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ORIGINAL ARTICLES.

I.—Coral in the "Dolomites" of South Tyrol.

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(Part II.)

(PLATES II. & III.)

(*Concluded from the January Number*, p. 10.)

III.—Transitional Dolomitic Era—Extremes of Rock-Facies in Raibl Times.

The Raibl period was the natural sequel of the variable and unequal movements which prevailed over Alpine areas in Permian and pre-Raibl Triassic time. Many basins formerly open were then enclosed; rauchwackes and beds of dolomite and gypsum were interbedded with fossiliferous deposits. Whereas, in some places, the dolomitic nature of the deposit is confined to special horizons, in the South Tyrol "Dolomites" it may almost be said to reign throughout. This makes it all but impossible to say when Schlern dolomite ends and Raibl beds begin. In the present incomplete state of our knowledge with regard to the heteropism of the Raibl series throughout the whole Alps, I have judged it best to begin the Raibl horizon at any particular place with the first appearance of a distinctly Raibl fauna, even although that fauna may not have been proved to correspond to the acknowledged lowest fauna of Raibl age in distant parts of the Alps.

To return for a moment to the succession of Schlern dolomite upon the Cassian beds of Enneberg, I found that, where Schlern dolomite rests on Cipit limestones, it has at its base a conglomeratic appearance, as if Cipit blocks had been imbedded in a beautifully fine white or reddish dolomitic mud, instead of the dingy brown and black tufaceous sediments. This is the case in several places, *e.g.* upon Pordoi and Sella Jochs, where there is no evidence of unconformity. Again, where the dolomite succeeds the thin-bedded marls and limestones of Cassian age, it does so conformably; but one and the same bed is at some parts calcareous and fossiliferous, at other parts dolomitic and unfossiliferous. Seeing that this holds good at various horizons in Lower as well as Middle Trias over the whole area of South Tyrol, we need find nothing remarkable in it from the point of view of the stratigraphical succession. Indeed, I have only mentioned these observations as an indication of the

particular mode of transition from conditions of deposition favourable for the Cassian fauna to those in which the Raibl fauna was enabled to make an occasional appearance in the South Tyrol dolomites. At a very little distance above the base of Schlern dolomite all signs of Coral life disappear, and the deposit looks a homogeneous rock, although always retaining local variation in the degree of its dolomitism. At this stage the rock often shows typical Oolite structure. As regards the presence or want of stratification, it has as little to do with the question of the Coral Reef origin of the dolomite as the amount of magnesic salts in the rock—stratification is present and absent in one and the same "Reef."

In the highest horizons of Schlern dolomite there is infinite irregularity in the relations of fossiliferous and unfossiliferous beds; these horizons have been proved palæontologically to belong to the Raibl period. In them Corals and Echinoderms reappear again in some abundance in the Gröden and Enneberg districts. Dolomitic shales may be regarded as the typical sediment, giving place locally to sandstones and limestones, in which strand-faunas and plant-remains are imbedded. In one or two places Corals formed thin reef-like extensions over preceding plains of algal and marine origin. The fauna everywhere has many reminiscences of the Cassian fauna, but has marked local as well as zonal characters. Thanks to the occurrence of a few leading Molluscan types of wider distribution in Raibl strata, one or two horizons of time are clearly identifiable in the succession. Life was often made impossible, and brightly-coloured magnesian marls silted up large basins. Dolomitic mud and rauchwackes accumulated, or beds of dolomite or gypsum were separated from the water in inland seas and lagoons of what seems to have been a South Tyrol "Raibl" Archipelago. The best example of the heteropism in Raibl times is afforded by Schlern Mountain, where the stratigraphical relations of the fossiliferous well-known "Schlern plateau" Raibl beds have been carefully worked out by von Wöhrmann.[1] He says: "At one place we have a fauna exceptionally rich in individuals, in others we find the same horizon represented by a Coral bank, or by ferruginous marls wholly unfossiliferous, etc. These contrasts cannot be explained merely by the irregularity of the sea-floor, which is readily recognizable through the rapid increase or diminution in thickness of the strata; we are bound to accept current action in addition, making the relations locally so favourable that a numerous assemblage of Bivalves, Gasteropods, and other organisms were able to thrive within narrow spacial limits (for instance, the immediate neighbourhood of 'Schlern-klamm') without spreading into the surrounding area" (*loc. cit.* p. 219). I have had experience of very similar facts at Sella, Sett Sass, and Lagazuoi. On Sella, as at Schlern, a Coral-bearing dolomite of no great thickness appears amid the dolomitic shales on the plateau. Again, on visiting the top of Lagazuoi, I found unfossiliferous beds of a hard dolomitic sandstone, perfectly

[1] Von Wöhrmann, u. Koken. "Die Fauna der Raibler Schichten vom Schlern Plateau." Zeitschrift d. D. Geol. Ges. 1892.

white, above the Schlern dolomite. From the occurrence of similar beds on the Sella massif, I took them to be of Raibl age, but followed along their dip to the north-east and saw their gradual passage into ordinary-looking yellow sandstones, with numerous fossils which proved to be the typical Raibl fauna of Travenanzes Valley. As the Travenanzes horizon is palæontologically younger than that of the Schlern plateau deposits, some part of the dolomite of Lagazuoi must in reality be of the same age as the fossiliferous Raibl beds of Schlern age. Thin beds of Cipit Limestones, like those of Cassian age, but much harder and whiter, occur at Valparola and Falzarego interbedded with the Travenanzes fossiliferous horizon.

Enough has been said to show that some of the anomalies of "Schlern dolomite" fall in the Raibl period, which has not been included by Mojsisovics in the Coral Reef epoch. Yet the heteropism of the Raibl strata adds to, and takes away from, the apparent thickness of the dolomite "reefs." It will be remembered that a younger or Upper horizon of fossiliferous Cassian strata is present in Ampezzo, which is absent in the Fassa and Gröden districts, and we know now that the upper part of the Schlern dolomite rock is contemporaneous with fossiliferous Raibl beds. Going a step farther, we can see that by thinning off the dolomite both at its upper and lower horizons, it would be probable enough, especially in the Ampezzo area, that fossiliferous Raibl strata should rest on fossiliferous Cassian strata. According to Mojsisovics, this is actually the case. My reasons for not adopting this view have been already stated (Quart. Journ. Geol. Soc. 1893, pp. 64–69). It is true that in these valleys the Schlern dolomite becomes comparatively thin, and it looks like the dolomite rock interbedded at higher horizons of Raibl strata. But even if the dolomite rock were wholly or in part contemporaneous with fossiliferous Raibl strata elsewhere (*e.g.* the Schlern plateau strata), this would in nowise afford evidence in favour of the Coral Reef theory, but only of the familiar fact of Raibl heteropism. The important feature is that the dolomite bears no evidence of Coral building, and is no thinning-out prolongation of a "reef"; but is here and elsewhere in the Cortina valleys an independent horizon of dolomite above the Cassian fossiliferous beds—it is, therefore, not Cassian "reef-dolomite." The varying relations of Cassian, Schlern dolomite, and Raibl strata are represented in Diagram IV.

The Raibl deposits pass quite gradually into the overlying true marine deposit, Dachstein dolomite, with which an important faunal link connects it. Several species of the bivalve *Megalodon* appear in the highest Raibl strata, and this is the predominating genus in Dachstein dolomite. There are dolomite shales of Dachstein age undistinguishable from those of Raibl age, and dolomitic marls make their appearance now and then in true Dachstein horizons.

The two rocks, Schlern dolomite and Dachstein dolomite, are so much alike that one experiences in the field the utmost difficulty in distinguishing them. The characteristic Dachstein bivalves so common in some parts of the rock are entirely absent in others.

Here we see an easy loophole of misconception in working out the stratigraphy of this area. How frequently it has given rise to error becomes apparent on comparing the maps or sections of different authors who have surveyed in the district!

An impression will now have been gathered of my opinion with regard to heteropism in the "Dolomites." Beyond doubt that exists, and to a very large extent; it alone explains the succession of Triassic rock in the "Dolomites." There are also reef-like communities of Corals, and of other fossil organisms, changing with the actual depth of the water and the character of the surrounding sediment. The Corals have but their fair share, along with other groups of marine life, in the thickness of any one formation, and just as important as the organic causes of heteropism are the inorganic. Most of all, the clear presentation of two epochs is necessary—the one is the volcanic period of Wengen age, when so many inequalities were introduced into the relief of the sea-floor and differential movements were set up in the basin of that part of the South Tyrol Triassic sea; the other is the Raibl period, and what it tells us of the culminating point in an age of unequal deposits and especially fluctuating conditions of level over these "volcanic" areas.

IV.—Apparent "Reef-Formations" in the "Dolomites" largely result from the particular history of Earth-movements in that area—Occurrence of Vertical and Inclined Planes of Fault in the "Dolomites"—Overthrusts—"Overcast" Bedding—Effects of Weathering.

Gradually the waters of the Rhætic and the great Jurassic ocean advanced over Alpine areas and the deposits of the Triassic Archipelago lay sleeping at unknown depths below a heavy weight of marine accumulations. The South Tyrol Trias and younger deposits alike shared in the tektonic movements which passed over the Alps during the long geological "days" of Mesozoic and early Tertiary time; but probably it was not until the Tertiary mountain-making period that the series of deposits was affected by tearing or sliding movements.

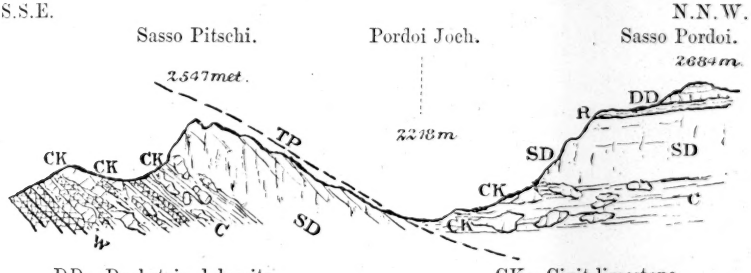
Tertiary movement begins a much more difficult chapter in the past history of the South Tyrol dolomites than the period of Triassic deposition. And we might be content to omit it entirely from present consideration, were it not that it produced many results in South Tyrol which cannot be dissociated from the "Coral Reef" question. It has left its symbols indelibly written on the rocks of the country, symbols as strange and as impossible of interpretation for the early school of geologists as ever were the ancient characters on the colossal monuments of Egypt and Syria for the unpractised eye. And when we learn to read, one of the first Miocene symbols in the "Dolomite" spells "*R e e f*" and is, being translated, *reduplication and faulting of rocks.*

The presence of a great number of vertical faults within the areas of Enneberg and Ampezzo has been already proved, also the influence of those in complicating the geology of the district and producing

apparent reef-structure as at Sett Sass (Quart. Journ. Geol. Soc. 1893, pp. 58–77). I wish now to refer to inclined fault-planes. Mojsisovics first hinted at their occurrence in the dolomites,[1] *e.g.* "on the slopes towards the Duron Valley a partial overturning, or perhaps more correctly, over-thrusting of Werfen shales over Muschelkalk dolomite seems to have occurred. The exposures along the road leading from the Duron Valley up Col Rodella scarcely permit of any other explanation. *At the edge of the Rodella Fault-block Melaphyre dykes occur south-west of Col Rodella*" (*loc. cit.* p. 189; the *italics* are mine).

I drew attention to the occurrence of fault-planes with extremely low hade in the Dürrenstein Mountain, and again in the Buchenstein Valley, north of Arabba; but, as the subject was a large one, and as I had not then completed my survey of the Buchenstein and Sella districts,[2] I avoided treating it within the scope of my previous paper. The planes at Dürrenstein hade south, the plane I referred to in Buchenstein was an overthrust fault-plane hading north. Dr. W. H. Salomon published a preliminary note[3] of his survey in the district of Marmolata Mountain, south of the Buchenstein and Cordevole Valleys, in which he reports that two overthrust fault-planes occur on the southern slopes of Marmolata hading north.

I shall at present confine myself to one typical example of the occurrence of an overthrust plane and its explanation of an apparent



DD = Dachstein dolomite.
R = Raibl Marls.
SD = "Schlern dolomite" and limestone.
TP = Thrust-plane.
CK = Cipit limestone.
C = Cassian strata.
W = Wengen strata.

"Reef" in the district personally surveyed. The example selected is Sasso Pitschi (see accompanying section), a dolomite summit south of the Sella massif. It is a reef-like mountain, standing up from the midst of Wengen beds on the Pordoi Joch. As will be seen from the description given by Mojsisovics (*loc. cit.* p. 238) the interbedding

[1] At the British Association Meeting in Edinburgh, July 1892, Prof. Lapworth, towards the close of his Presidential Address to the Geological Section, referred to the country of the dolomites as one which he believed would be found to be cut by a great many overthrust fault-planes.

[2] I hope soon to publish a geological map of the district between Sella Joch and Wolkenstein on the West, and Cortina d'Ampezzo on the East, surveyed to scale 1 : 25,000; and to give along with it a complete statement of my results.

[3] Dr. W. H. Salomon, "Ueber den geologischen Bau und die Fossilien der Marmolata," Verh. der k.k. geol. Reichsanstalt, 7th March, 1893.

of Cipit Limestones with tufaceous rocks is peculiarly characteristic. The dolomite rock contains, especially at its base, remains of Corals and Crinoids. *Ammonites* also have been found in the dolomite. I find it impossible to consider the succession on Pordoi Joch undisturbed. On the south side, the Wengen lavas dip N.N.W. (20°–30°) and the conformable series of Cipit Limestones (Wengen and Lower Cassian age) and Schlern dolomite beds dip in the same direction at a rapidly increasing angle. The rocks on the north or Sella side are, on the contrary, remarkably horizontal, but where the terrain descends from Sella Mountain to Pordoi Joch, the strata dip slightly southward and south-eastward, *i.e.* outward from Sella (a dip which the strata exposed on the lower half of Sella massif continue to have all round its eastern side). On Pordoi Joch, therefore, we are presented with a repetition of the Cipit Limestone and the dolomite strata, owing to the passage of an overthrust plane of low hade, above the Sasso Pitschi rock. The thrust-plane hades northward and cuts away the dolomite rock of Sasso Pitschi, both in its eastward and westward extension below the Cassian beds of the Sella block. This fault affords to my mind a simple explanation of all the appearances associated with "Coral Reef":—

1. That Sasso Pitschi appears to "rise out of Wengen beds"
2. That the dolomite rock of Sasso Pitschi has a steep cliff edge to the south, and a gentle slope to the north.
3. That it thins out on Pordoi Joch, except on the western side, where it *appears* to pass conformably under the dolomite rock of Sella massif.
4. The "overcast bedding with northerly dip" said to be observed on the northern slope of Sasso Pitschi.

This last-mentioned appearance is clearly shown at Sasso Pitschi, and is by no means the only case in which I believe it to be the result of fault movement. The thrust-plane observed at Sasso Pitschi may be followed with N.N.E. outcrop close under the cliffs of Sella to Pian de Sass, where it also explains the seeming anomalies of the succession. If we now proceed to mend this broken section according to the natural succession of the district, we have a fair representation of the particular volcanic zone from east to west, already referred to (see Diagrams I.–II.). Here, where we are on the borderland of the actual passage of Wengen and Cassian strata into their deeper sea equivalents, the main thickness of these beds is composed of volcanic lavas and tufaceous deposits. The Cipit Limestones and the Sasso Pitschi "dolomite" may of course be regarded as the direct continuation northwards of the upper part of the Marmolata deposit of limestone and dolomite, continued further north over Sella, Gardenazza, etc. This is an example perfectly analogous, therefore, with the case of the heteropism at Schlern Mountain, on its southern and northern sides, and the Seisser Alpe. There is scarcely any thickness of the Cassian horizon present below the Schlern dolomite of Sasso Pitschi; the Middle Cassian or "Stuores" zone partly developed as "Cipit Limestones" on the Sella slopes, passes to the east and north-east into the thin-bedded fossiliferous marls of Enneberg, and reaches a later palæontological development on these meadows than below Sella and Sasso Pitschi.

I have dwelt at some length on this example, because it shows again the tektonic nature of some of the difficulties hitherto professedly explained by the "Coral Reef theory." We must in every case clearly decipher the twofold nature of the difficulties in South Tyrol, for, as we have seen both at Sett Sass and at Sasso Pitschi, the battle is only half fought with a knowledge of the Triassic period. In the latter case, Sasso Pitschi, the heteropism of the Wengen and Cassian strata, together with the conformable succession of "Schlern dolomite," are the stratigraphical truths observed at Pordoi Joch. The tektonic fact is the overthrusting from the north of the system or "block" of strata belonging to the Sella massif along a plane formed in this southern part by the cut and tilted ends of the strata belonging to the fault-block of Sasso Pitschi and Cima Rossi. It is not necessary for the purpose of the present article to follow farther the course of this thrust-plane, or to describe in detail others which exist in the districts of Enneberg and Ampezzo, Buchenstein and Upper Gröden. For the Pordoi overthrust is not an isolated occurrence, but one of several inclined planes of fault which pass through strata of all ages in this part of the "Dolomite Alps." Above Pian de Sass, on Sella Mountain, an overthrust fault passes through Dachstein dolomite, and just north of the Boe Spitz (the highest ridge of Sella) a fault plane with reversed hade has raised Dachstein Dolomite against Jurassic strata. The direction of these faults is S.S.W.—N.N.E., and they afford the most perfect analogy with the main faulting which has taken place in districts west and south-west. Suess says, in summing up the observations of faults in the Southern Alps (east of the Judicarian fault): "Long flexures have occurred passing locally into faults, which, running parallel to the Judicarian line, have let down the strata on the eastern side, and have caused overthrusting to the east, or more correctly from a W.N.W. direction towards E.S.E. These extend from the Judicarian line as far as the left side of the Etsch below Peri. Further, similar flexures have occurred which run more or less parallel with the Asta faults, lie south of these, and have let down the strata on the south, and sometimes overthrust them to the south. Some of the Judicarian faults swing round in sharp curves, in the proximity of the Etsch Valley, into the direction of the Asta faults" ("Das Antlitz der Erde," Bd. I. pp. 334-335). It is just such a swing-round that the inclined fault-plane of Pordoi and Sella shows, and I may state generally that the faults of Sella may be grouped with the Judicarian system, whereas those of Gröden Joch, of Buchenstein Valley, and, in short, the faults in this area which pass through anticlines of the deeper lying Triassic strata, belong to the Asta series. No hard and fast distinction can be drawn between these systems; they pass into one another and form one complicated system of movements, which may be proved even in the small district of Enneberg to have affected the positions of both Triassic and Mesozoic rocks.

By reason of these faults, the dolomitic rock has sometimes been

so placed with regard to the earthy deposits below or above as to look like an independent reef from the midst of sedimentary rocks of its own age. Or it has been doubled upon itself, and thus, apparently, attains a much greater thickness. The harder rocks of Schlern and Dachstein dolomite have sometimes been pushed into new positions over the slipping substratum of earthy rocks without themselves undergoing much relative change of position or perceptible evidence of strain, except when complications are introduced by minor thrusting and faulting along the main planes. I hope to find out from specimens collected if any degree of internal change in the crystallization of the rocks may be due to thrust-strain. Visible signs of this strain are given by the "overcast bedding" at Sasso Pitschi and on the east side of Sella.

The appearance called "overcast bedding" is not always a concomitant of a thrust-plane, but is sometimes occasioned by the outward dip of the dolomite strata from the mountain. The weathering of the rock then produces a characteristic effect, *e.g.* on the west side of Dürrenstein, where the strata dip west; on the north side of Sett Sass, where they dip north; on the east side of Sella, where they dip east, etc., etc. Another form of "overcast bedding" is produced in the Cassian strata. The tufaceous or marly beds surrounding Cipit Limestone are worn or washed away more rapidly than the Limestones which gradually fall over and strew the steep slopes below the dolomite rocks. This is also a common reason why the reef-limestones predominate more, to all appearance, in the neighbourhood of the cliffs than on the less steeply inclined gradients of the "Alpen" or meadows.

A curious and particularly pleasing appearance is produced where a mountain slope of Schlern dolomite has been gradually denuded by snow and ice, wind and weather, of its Raibl "robe of many colours." Patches of greenish or reddish marls, from the size of a bean to the roof of a house, are left upon the pure crystalline whiteness of the dolomite. The sunlight sends its gleams upon it till the cold rock is lit with life, and the shimmer that runs through the leaves of an autumn forest is not more beautiful. All the more strange is the contrast to the Alpine climber when he reaches the top and finds on the other side of the mountain a giddy precipice of apparently unbedded rock. We cannot wonder that the idea of steep Coral cliffs facing the broad ocean and shelving inwards into calm bays and lagoons has long held its own in the mind of many as a fitting theory of the origin of such wonderful mountains! Beside it, any other explanation pales, and seems beset with endless complications.

For no sooner does one realize the main laws attending Tertiary movement in the "Dolomites" (a series of wide folds running, roughly speaking, east and west; anticlines segmented by steep fault-planes which meet and intercross as at Gröden Joch, or by overthrust fault-planes as in the Buchenstein Valley; synclines sinking unequally in many detached pieces, *e.g.* the Tofana and Kreuzkofl massif, Sett Sass, etc.), than new difficulties present themselves.

V.—Complete Harmony of the Geology of Enneberg in South Tyrol, with recognized methods of Alpine Mountain-making.

Since the main folding and overthrusting and East-West faulting took place, these planes of fault and the strata through which they passed have continued to suffer from movements of a vertical nature and usually in transverse direction (*cf.* Vacek's observations on North-South faults in the Etsch basin). For example, I have already referred to an important thrust-plane in the Buchenstein Valley. It may really be better called an east and west direction of over-thrust faulting, for the main thrust is made up by the coincidence of several minor overthrusts, and it breaks eastwards into a number of diverging overthrusts. The whole series of faulting is cut off just west of the Arabba stream by a vertical fault of considerable throw, extending north and south, and letting down the Sella block in the west. This fault passes through the western limits of the Prelongei and Stuores meadows, while the Buchenstein over-thrust lies on the southern. Another important North-South fault occurs between Cherz and Varda, in the Buchenstein Valley, again letting down the western flank. What do we find now on the northern and eastern limits of Prelongei? Northward, the squeezed and shattered anticline of Gröden Joch passes across the meadows and is cut off by the north-south vertical fault traced southward from Heilig-Kreuz.[1] The mountains of Kreuzkofl and La Verella are let down to the east of this fault until Dachstein dolomite reaches almost the same low contours as it does at the Sella massif (eastern side), and at Sett Sass. We see, therefore, that the Cassian strata of Prelongei are pressed like a pliable plug into the midst of an ancient arena of cross-movements. And in this light the theory that the fossiliferous Cassian deposits collected in a basin more or less surrounded by high Coral cliffs of Sett Sass, Sella, Lagazuoi and Gardenazza, sinks into insignificance, for here we have something much grander! These are the processes of ages which have given us our grand Alpine Chains. The meadows of Enneberg have in *this* history one which will bear comparison with the proudest tales of Switzerland. They give us their trophy of miniature forms of mid-Triassic life; they give us also an insight into Nature's methods of mountain-making, on a miniature scale it is true, but following natural law as inevitably as did the spirals of their thousand Gasteropods, or the delicate intricacies within their myriad Brachiopods.

I must for one moment refer to the latest volcanic eruptions which took place, presumably also in Triassic time, in the districts of Predazzo and Monzoni (Fleims and Fassa Valleys). The innumerable dykes of the district often penetrate Wengen lavas and Schlern dolomite, and are said to be limited to a certain radial distance from the chief centres of eruption. The northern limit given, viz. Rodella, Canazei, and Marmolata, for the occurrence of intrusive porphyry in rocks younger than Lower Wengen, must, however,

[1] *Vide* Q.J.G.S. 1893, "General Map," p. 70, where the important faults in the Prelongei district are drawn.

be extended to include the meadows of Prelongei, for in them I found intrusive sheets penetrating high horizons of Cassian strata,[1] and producing contact-metamorphism in sedimentary beds above and below. At Gröden Joch,[2] and in the Buchenstein Valley, dykes of porphyry occur in Lower Trias and Wengen horizons. Where they pass through Upper Muschelkalk, they have converted it *in situ* into a brecciated rock, or sheared it into shaly layers. Both on Gröden Joch and on the Buchenstein cliffs the porphyry is exposed in the main fault-lines which cut through these two anticlines of older Trias. In the Buchenstein Valley, above Varda, the volcanic rocks are hopelessly mixed up with the overthrust beds of Lower and Upper Muschelkalk and Buchenstein strata, but they are absent in the highly-folded succession of the same rocks below the thrust-plane, at Ruaz, or in the series of radiating faults below Pieve. Further detail I cannot give in these pages; I would only indicate the natural considerations which suggest themselves with regard to the age of the intrusive sheets. Two hypotheses may be stated:—(1) The intrusions of Augite Porphyry in these cases may be of Triassic age, exposed along with the Triassic rocks through which they penetrated, by later faulting and erosion. Since they, as well as the lavas of distinctly Wengen age, often occur along the path of faults, it would seem that the Judicarian-Asta system of faults followed largely ancient lines of weakness, which had been marked by the outbreak of lavas in Triassic time, or intrusions of porphyry of uncertain age. (2) The idea that the intrusions may have been associated with Tertiary movements in the Alps is not supported in Enneberg, but rather the evidence shows that at this period the volcanic rocks, both contemporaneous and intrusive, behaved as a compact, united mass, along with the sedimentary rocks.

The Buchenstein Valley finds its tektonic continuation in the Pordoi and Rodella district, where, as a previous quotation shows (p. 53), the facts appear to be in the main analogous. If we now compare the great "Eruptive Fault" of Fleims and Fassa, we find that by its throw at Sattel Joch, the northern wing of the fault is Lower Trias, faulted to the same level as Schlern dolomite on the south. The "Eruptive Fault" changes in its relations at Viesena, but it may be traced east and west through the country to a considerable distance from the actual eruptive centres. Here and there along its main line or its radiating branches, dykes of porphyry and melaphyre occur, just as in the fault-lines further north. I should think there could be little doubt that these great longitudinal fault-lines, together with the parallel Villnös fault in the north, were developed under the same general conditions, and were for the most part of pre-Tertiary origin. These faults have all been important planes of movement since Mesozoic time. Tertiary faults in some places coincide with, or cross at varying angles, lines of Triassic disturbance. Where areas

[1] Q.J.G.S. 1893, *loc. cit.* p. 18, Map A.

[2] Cf. von Richthofen, *loc. cit.* p. 133, etc., who notes the occurrence of intrusive rocks at Gröden Joch.

already considerably faulted have been affected in this way, the ultimate results may seem conflicting. More especially might this be expected in the Fassa or Rodella districts, but no such complication would gainsay the striking analogy which the "Eruptive Fault" of Fassa presents in its main tektonic aspects with the faults of Buchenstein and the Gröden Joch.

VI.—Conclusions with regard to Coral Formations in the Dolomites.

We are now in a position to examine more closely the points of agreement and difference which Coral formations in the Dolomites present with the various theories of Coral-reef growth. Mojsisovics[1] has clearly shown to what a great extent variation in the rate of subsidence and the depth of the sea-floor has influenced mid-Triassic deposit in South Tyrol. Rothpletz, in his most recent work,[2] has discussed the entire question and brought forward the importance of submarine banks of sediment. While I have attempted to indicate an irregular sea-floor in Diagrams I. to IV., I designed those diagrams mainly to show one or two other facts of almost equal importance: (*a*) that coralline "Cipit Limestone" and Coral Dolomite form comparatively small thicknesses of interbedded rock and not the main body of the mountain masses; (*b*) that Corals began to grow in Wengen time on a submarine volcanic ridge on the northern edge of a great area of subsidence, and travelled inward and northward in Cassian time; (*c*) that extensive banks of Coral were formed in scattered localities during the Raibl period of shallower water and Dolomite deposit.

The Coral-blocks and lenticular "Cipit Limestones" were, therefore, to begin with, members of a submarine barrier-ridge, and never were strand-reefs. There was, from early Wengen time, an inner protected part of the sea whose bed, so far from being deepened in the way indicated either by Murray or Guppy, was constantly being shallowed by the rapid accumulation of shore sediment and the intermittent eruption of porphyry and lava. The movement was one of subsidence, proved by the fact that the Corals moved northwards, or inwards, in the later Cassian periods, and gave place, along the old Fassa-Gröden barrier, to the formation of marine Calcareous deposit. Probably occasional stationary intervals retarded the subsidence of this inner sea, and were, so far, favourable for Coral-growth. Several authors have called attention to the evidence of the action of currents in those areas. The vicinity of land is proved by the frequency of plant remains everywhere in the Wengen sediments. In the Cassian strata of Enneberg these are very rare; on the other hand, in the Ampezzo district, fragments of stems and leaves are common at certain horizons of Cassian and also of Raibl strata, and were not unlikely swept here by some wide river-channel from the north-west. The area of depression,

[1] Mojsisovics, "Dolomit-Riffe," etc., pp. 505–510, and more especially for general tektonic relations, chap. xvii.

[2] Rothpletz, "Ein geologischer Querschnitt durch die Ostalpen," Stuttgart, 1894, pp. 52–67, "Ist der Schlerndolomit ein Korallenriff-Bildung"—a full discussion of the question.

south of the Fassa-Gröden barrier, extended also considerably westward; it was a basin in which, during Permo-Triassic time, volcanic activity was never long absent.

Comparing now the conditions existing in the West Indies at present, the resemblance is most striking. We read from Langenbeck[1] that barrier-reefs "have built on the outermost edge of extensive banks of sediment which have been heaped up along the whole North Coast of Cuba by sea-currents" (*loc. cit.* p. 18); and again, "It is exactly this difference in the degree of subsidence which produces the contrasts (so very characteristic of the north-west part of the Caribbean Sea) between great oceanic depths and relatively shallow portions of the sea, the two abutting almost directly on one another, united by steep slopes" (*loc. cit.* p. 24). In the Australasian Archipelago we find essentially similar physical and natural phenomena—in the Philippine Islands, the Solomon, Pelew, and Fiji Islands, etc. There too, reef-Corals show special favour for submarine ridges and plateaux in the immediate proximity of areas of strongly-marked subsidence, and very generally where volcanic agencies have recently been, or still are, active. Everyone conversant with the literature of recent Coral-reefs will recall abundant testimony of the co-operation of the same great geophysical forces which influenced the Triassic seas of South Tyrol, and made them locally suitable for the existence of beds of reef-Coral and the development of a rich fauna.

Guppy and other observers have stated that during "negative," or shallowing movement, Corals grew seldom in reef-like fashion; they tended rather to spread laterally and form extensive banks, or even terraces. This is admirably illustrated by the Coral-banks of the Raibl period. Their mode of occurrence reminds one, too, of the "Coral Oolite" beds of Jurassic deposits. The Coral rock formed in South Tyrol in Raibl time is not Limestone; it is a member of a highly Dolomitic series and is itself Dolomitic. It must be remembered that the Dolomitism of the Raibl-Dachstein period is by no means confined to South Tyrol, but is a common feature in greater or less degree in the Alps and in Keuper deposits elsewhere. The volcanic eruptions of Predazzo and Monzoni have been attributed to the early part of the Raibl period. This would conform with the local oscillations of level in neighbouring areas and the temporary "back-flow" of the water. The Pelew and Fiji Islands and the Sandwich Islands yield again good cases of analogy.

Darwin's theory demands fairly constant equipoise throughout a long geological age between the rate of growth of reef-Coral and the rate of subsidence of the reef-basis. There is *not* satisfactory evidence in favour of this in South Tyrol; my special survey in a part of the district seems to me to justify, without doubt, the position of those authorities who have contended that the immense thicknesses of "Schlern Dolomite" rock were an ordinary marine deposit and not "Coral-reefs."

[1] Dr. R Langenbeck, "Die Theorieen über die Entstehung der Koralleninseln und Korallenriffe und ihre Bedeutung für geophysische Fragen." Leipzig, 1890.

II.—On some Jurassic Species of Cheilostomata.

By J. W. Gregory, D.Sc., F.G.S.;
of the British Museum (Natural History).

THE extraordinary abundance of Bryozoa of the order Cheilostomata which occurs throughout the Cainozoic era, in comparison with their scarcity in earlier formations, has often been remarked. Interesting explanations of the suddenness of their appearance have, moreover, been offered by those who do not attach so much importance, as do some, to the imperfection of the geological record. Cheilostomata are not unknown from earlier deposits: the Cretaceous system has yielded a fair number, while even as early as the Silurian species have been found. Though doubts have been thrown on these early records, there seems no sufficient reason to discredit them. Even if Prof. Nicholson's *Hippothoa inflata* (Hall) [1] should turn out to be a *Stomatopora*, which, if the figure be correct, is most unlikely, there remain many species in later Palæozoic deposits: such are those belonging to Prof. James Hall's genus *Paleschara*,[2] which Mr. Ulrich [3] accepts as Chilostomatous, though Prof. von Zittel [4] includes it doubtfully with the *Ptilodictyonidæ*. Some of the specimens of *Lichenalia*, etc., figured by Hall,[5] as well as the same author's *Cystopora geniculata*,[6] may also belong to this order.

The Jurassic fauna, however, so far contains very few records of Cheilostomata, though Prof. Nicholson [7] remarks that from the Jurassic onward there are abundant remains of this group. Michelin has figured [8] a specimen which he has named *Eschara ranvilliana*, which certainly belongs to the Cheilostomata, though until its internal structure is known it cannot be definitely placed. It must be assigned to the suborder "Athyriata" and probably to either the *Microporidæ* or *Cellariidæ*. The latter is most probable, as species of this family occur on the same horizon in England. Haime [9] has recorded two species: *Terebripora antiqua*, D'Orb., which has not been figured, and the description is insufficient to determine the order to which it belongs; his second species is the *Cellaria Smithi*, Phillips,[10] which he follows Morris [11] in definitely including in

[1] H. A. Nicholson, Descriptions of Polyzoa from the Silurian Formation, Rep. Geol. Surv. Ohio, vol. ii. Palæontology. 1875. p. 268, pl. xxv. fig. 1. The *Alecto inflata* of Hall, Palæontology of New York, vol. i. 1847, p. 77, pl. xxvi. fig. 7.

[2] James Hall, *ibid.* vol. vi. Corals and Bryozoa, 1887, e.g. *Paleschara dissimilis*, p. 35, pl. xv. fig. 11.

[3] E. O. Ulrich, Palæozoic Bryozoa, Palæontology of Illinois, part ii. sect. vi. Geol. Surv. Illinois, vol. viii. 1890, p. 366.

[4] K. von Zittel, Handbuch der Palaeontologie, Palaeozoologie, Bd. I. Abth. I. lf. 4, 1880, p. 604.

[5] James Hall, *ibid.* vol. vi. 1887, *e.g.* pl. xxx. figs. 5 and 6; pl. xxxi. figs. 12, 17, 20, 22, and 29.

[6] *Ibid.* p. 103, pl. lxvi. figs. 7–9.

[7] H. A. Nicholson and R. Lydekker, a Manual of Palæontology, 3rd edit. 1889, vol. i. p. 634.

[8] H. Michelin, Iconographie Zoophytologique, Paris, 1846, p. 243, pl. lvii. fig. 12.

[9] J. Haime, Description des Bryozoaires fossiles de la formation Jurassique, Mém. Soc. Géol. France, ser. 2, t. v. 1854, p. 217.

[10] J. Phillips, Illustrations of the Geology of Yorkshire. Part I. The Yorkshire Coast. 1829, p. 143, pl. vii. fig. 8.

[11] J. Morris, Catalogue of British Fossils, 1843, p. 39.

Hippothoa. Phillips' figure is quite useless; but, with his usual courtesy, Mr. H. M. Platnauer has kindly lent me the type which is now in the York Museum; the species, however, certainly does not belong to *Hippothoa* as that genus is now defined.

In a paper on the British Paleogene Bryozoa[1] I pointed out the occurrence of *Onychocella* in the Jurassic, and, considering the rarity of known species of Chilostomata of this age, I take this opportunity, with the kind permission of Dr. Woodward, of describing this species and one of the genus *Membranipora*. Both specimens are in the British Museum.

Order: CHEILOSTOMATA.

Suborder: ATHYRIATA.

Family: MEMBRANIPORIDÆ.

Genus: MEMBRANIPORA, Blainville, 1834.

Species I.: MEMBRANIPORA JURASSICA,[2] n. sp. (Fig. 1).

DIAGNOSIS.

Zoarium: Erect, foliaceous, bilaminate.

Zoœcia: Regularly quincuncial, form hexagonal, slightly irregular. Opesia very large. Aperture occupying the whole of the opesium and markedly clithridiate in shape. Rim apparently plain, highest

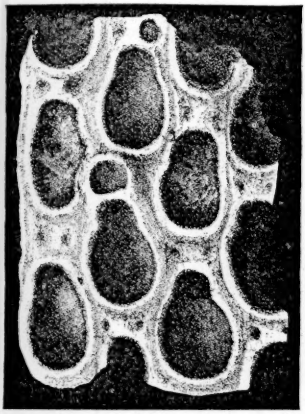


FIG. 1.

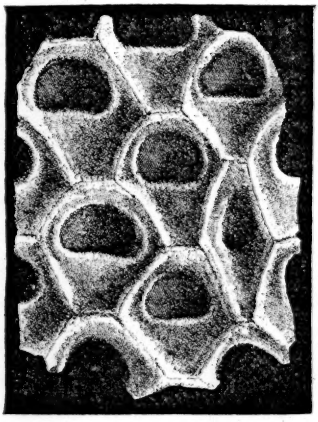


FIG. 2.

on the margin of the aperture, and sloping thence to the inter-zoœcial sutures. Front wall very small in extent, consisting only of a narrow space at the upper end of the zoœcium, sometimes replaced by oœcium.

Oœcium: Cucullate, reniform in shape, surrounded by a low rim. The oœcia are sparsely scattered over the zoarium.

Avicularia: Usually a pair at the upper corners of the zoœcium,

[1] Trans. Zool. Soc. London, vol. xiii. pt. vi. 1893, p. 239.

[2] So named as it is the first recorded Jurassic species of this genus and family.

but sometimes there is only one. The aperture is oval. They are medium in size.

Dimensions: Length of a zoœcium 1·3 mm; breadth 0·85 mm.

Distribution: Calcaire à polypiers. (Bathonian.) Ranville, Normandy, France.

Type: Brit. Mus. D 180.

Affinities of the Species.—This species belongs to a group which is well represented in the Cretaceous, and it is advisable to compare it with the following seven species. From *Membranipora bipunctata*, Goldf.,[1] it differs in that in the latter the aperture is oval, the zoœcia are less regular, and there is but one avicularium; the species are allied in general aspect and the structure of the rim. *M. velamen*, Goldf.,[2] resembles the new species in the shape of the aperture, but it has a more extensive front wall, larger (and possibly vicarious) avicularia, and the shape of the zoœcia is different. *M. cypris*, D'Orb.,[3] agrees in the shape of the zoœcia and the character of the rim, but has an oval aperture and no avicularia. *M. regularis*, D.Orb., agrees in the structure of the avicularia, but the other characters show that the species are clearly different. *M. tuberosa*, Novák,[4] agrees in its general characters, but it possesses numerous vibracularia and is more ornamented. Marsson's figure[5] of *M. lyra*, Hag., shows that this Maestricht species belongs to the same group, but it may be easily distinguished from *M. jurassica* by its oval aperture.

Family: Microporidæ.

Genus: Onychocella, Jullien, 1881.

Species: Onychocella bathonica, n. sp. (Fig. 2).

Diagnosis.

Zoarium: Encrusting; an extensive thick crust.

Zoœcia: Skittle-shaped, the lower part being like half a hexagon, closed above by a well-rounded arc. Aperture ovato-deltoid with a blunt upper end; the lower margin is entire and but slightly curved and has a somewhat raised thin margin; the aperture is large. Front wall small, triangular, depressed; minutely granular. Raised rim, plain, non-crenulate.

Avicularia: Large, vicarious; long, tapering at each end; irregularly scattered over the zoœcium. Apertures obovate. A small, triangular front wall both above and below the aperture.

Dimensions: Length of a zoœcium; 1 mm.; breadth, 0·8 mm.

[1] *Cellepora bipunctata*, Goldfuss, Pet. Germ. Bd. I. Ht. 1, 1827, p. 27, pl. ix. fig. 7, and Hagenow, Die Bryozoen der Maastrichter Kreidebildung, 1851, p. 76, pl. ix. fig. 9.

[2] *Cellepora velamen*, Goldfuss, *op. cit.* p. 26, pl. ix. fig. 4, and Hagenow, *op. cit.* p. 97, pl. xii. fig. 1, in which the type is refigured.

[3] Pal. Franc. Terr. Cret. t. v. p. 551, pl. 607, figs. 11–12.

Flustrina regularis, D'Orb., *ibid.* p. 306, pl. 702, figs. 17–19. *Flustrina elegans*, p. 302, pl. 701, figs. 17–19, appears to be only a worn variety of this species.

[4] Novák, Beitrag zur Kenntniss der Bryozoen der böhmischen Kreideformation Denk. k. Akad. Wiss. Wien. Bd. xxxvii. Abth. II. 1877, p. 92, pl. i. figs. 1–3.

[5] Th. Marsson, Die Bryozoen der weissen Schreibkreid der Insel Rügen. Pal. Abth. Bd. IV. Ht. 1. 1887, p. 59, pl. v. fig. 17.

Distribution: Calcaire à polypiers (Bathonian.) Ranville, Normandy, France.

Type: Brit. Mus. D 181.

Affinities.—The closest allies of *Onychocella bathonica* are four species from the Cretaceous, which have been described under other generic names. It is unfortunate that there is some doubt about its nearest ally, a Maestrichtien species, described by Hagenow; in his monograph he has given two figures[1] which he assigns to the species *Cellepora* (*Discopora*) *koninckiana*; but the structure of the aperture is so different in the two, that I feel bound to assign them to different species: in his first figure the aperture is mucronate and is small; in the second (fig. 11) the aperture is elliptic, with the longer axis longitudinal, the lower margin is entire, the aperture occupies twice as large an area as in the former, and the avicularia are much larger. I therefore make Hagenow's second figure (fig. 11) into a new species under the name of *Onchyocella hagenowi*. This is the nearest ally of *O. bathonica*, but it differs in the larger size of both the avicularian and zoœcial apertures.

Onychocella piriformis (Goldf.)[2] is another ally, but has a lower zoœcial aperture, while the avicularian aperture is larger and the front wall occurs only above and not on both sides of this. *O. santonensis* (D'Orb.)[3] has a smaller mouth and longer avicularia; *O. solea* (Novák)[4] a semi-elliptical aperture with a mucronate lower margin.

The result, therefore, of the present communication is the first description of Bryozoa of the order Cheilostomata in the Jurassic; the species described belong to the two families of the *Membraniporidæ* and *Microporidæ*; but representatives in this age of the *Cellariidæ*, *Smittidæ*, and other families are also included in the British Museum Collection.

III.—Notes on the Composition of Clays, Slates, etc., and on Some Points in their Contact-Metamorphism.

By W. Maynard Hutchings, Esq.

(*Concluded from the January Number*, p. 45.)

After this substance has been well observed in good occurrences, it is always recognized at once, even as isolated small patches in a slide. It has a very characteristic appearance among the other constituents. It is marked off, for instance, by its special refraction from anything else that occurs in these rocks, and has other characteristics not to be missed when once observed, but not very easy to exactly describe. As soon as it ceases to be quite inert in polarized light, as soon as the speckly polarization sets in, it has also a more or less granular

[1] Hagenow, *op. cit.* p. 95, pl. xi. figs. 10 and 11.

[2] *Eschara piriformis*, Goldfuss, *op. cit.* p. 24, pl. viii. fig. 10; Hagenow, *op. cit.* p. 75, pl. ix. fig. 6; pl. xi. fig. 6.

[3] *Eschara santonensis*, D'Orbigny, *op. cit.* p. 109, pl. 603, figs. 1–3; pl. 373, fig. 4.

[4] *Biflustra solea*, Novák, *op. cit.* pp. 94–95, pl. iii. figs. 12–16.

appearance in ordinary light with lowered condenser, which is very characteristic. In different slides, and often in one and the same slide, various stages of development may be observed in it from the first speckled appearance in polarized light up to a point where flakelets of white mica are recognized as forming in it, lying "criss-cross" in all directions. It passes in this way in some cases almost wholly into mica, with apparently other substances which cannot be identified with certainty, the transition, and connection with the original substance, being all the time distinct and beyond mistake.

In the inner zones, the "hornfels-zones," this substance is usually present in smaller amount, as already stated; but examples of its abundant occurrence are not wanting, as for instance in a hornfels from Spitzenberg, in the Harz. There is a mosaic of quartz and felspar, with brown mica and some white mica. The yellow substance lies in amongst, and surrounds, the minerals of this mosaic. It has no definite form of its own, simply occupying spaces and taking the outlines of the other minerals. It is all either in the minutely-speckly stage or variously developed from this upwards to mica; and the impression made is that if it had all developed as far as some portions of it have done, the whole mosaic-grains of the slides would be mixed in with and surrounded by white mica, as may not infrequently be observed in these contact-rocks.

Before discussing the probable nature of the substance above described, I will recur to the spots in the contact-slates at Shap. These spots are all marked off sharply by being relatively free from biotite in a rock which is very rich in that mineral, so that they appear by comparison in ordinary light as clear spaces, varying from almost colourless to a good deep yellow in some cases. The aggregations in them of anatase, ilmenite, etc., have been formerly described by Harker and Marr and myself (Quart. Journ. Geol. Soc. vol. xlvii. 1891; and Geol. Mag. October, 1891).

Examination in polarized light shows them to be of several kinds, and when a sufficient number of specimens are examined it does not appear possible to point out any special development in their nature as taking place steadily as we approach the granite. Indeed, it may be remarked of the contact phenomena in general that they are somewhat erratic as we approach the contact up Wasdale Beck, which may probably be due to irregular contour of the granite below the surface.

Harker and Marr look on these spots as being "evidently imperfect crystals, charged with a large quantity of foreign inclusions," pointing out that some of the spots are sufficiently individualized to extinguish, as to their main constituent, pretty uniformly over the whole area and frequently parallel to the longer axis. They think the mineral present is likely to be andalusite, and I was formerly of the same opinion, but after renewed examination of the slides I am no longer so. Further study of the spots of this nature, and careful comparison of them with some continental occurrences, show that cordierite is the mineral in question. It is tolerably

abundant in some parts of the Shap contact near to the granite outcrop. Some slides from these parts are very closely paralleled by examples from the Elbe Valley contacts described by R. Beck (*op. cit.*), who says of some of them, "Cordierite represents the spots of the Knotenglimmerschiefer, which do not otherwise form any definite mineral." The cordierite of the Shap rocks is not in any way distinguishable from that of some of the rocks from the district described by Beck, sections of which I have examined, and also closely resembles the occurrences in rocks from the Lausitz district of Saxony. This, then, is another case in point where a definite mineral is formed in a rock wherein the real "spots" have not yet wholly died out, though less abundant than in the outer zones. There is nothing really to lend weight to the idea that any of these spots consist of andalusite, and this mineral is not detected in any of the altered sedimentary rocks at Shap.

Other spots, as previously stated, consist almost wholly of white mica, newly formed and full of quartz-grains and other things in the usual manner of this newly-formed contact-mica.

With these, and still more as we recede from the granite outcrop, are the true "spots," more or less closely resembling those above described, containing the substance in question in all its stages from amorphous, through minutely cryptocrystalline up to a definite micaceous development. And the same substance occurs in some slides outside the spots, or where these are quite absent, lying in among the mosaic minerals or surrounding them in the usual characteristic manner.

It remains to consider what may possibly be the nature of the substance seen so abundantly in the contact-slates from widely separated localities, and what are likely to be the processes to which it, and some of the other phenomena observed, owe their origin.

The first thing to remark is that the substance in question, whatever may be its exact nature, is certainly quite a *new formation*. It does not correspond to anything that can ever be observed in normal slates or shales, and we see that when it first makes its appearance in the slates, at the outer parts of contact-zones, it is mainly limited to "spots" and is in some way correlated to the "aggregations of dark grains"; also that these dark grains are very frequently to a large extent small plates of ilmenite, or crystals of anatase, or re-formed crystals of rutile, all of which either did not exist in the normal slate, or existed in a different form and not aggregated. If we consider how these aggregations of recrystallized minerals were caused, we cannot very well conceive of any process by which they migrated, recrystallized, and aggregated together *as such*. Thus, taking the simplest case, that of rutiles, in which a mineral has simply increased in size and aggregated, and not a case in which its material has reappeared in a new form, as rutile changed to anatase, or combined with iron-oxide as ilmenite, —we cannot assume that for each one of the larger and more perfect crystals seen, several of the minute "clay-slate needles" have travelled in the rock and simply combined to make one larger

individual. If this could take place at all it would only be conceivable at a temperature which rendered the rock plastic, and even supposing this condition may be attained close to contact we have every evidence that nothing at all approaching to it occurs at the outer zones. We seem to have only the one explanation which harmonises with all we can observe, that this aggregation of the minerals in question is due to *solution* and recrystallization. We know that no mineral is absolutely insoluble, even in distilled water, under ordinary conditions. Rutile, *e.g.*, has been used by Dœlter as an example of this fact in his experiments. We know that increase of temperature and pressure, even in the moderate range we can command experimentally, enormously increase the solvent action of water, and that in saline solutions still greater effects can be produced.

For the observed phenomena of contact action it seems natural to conclude, and probably most people do conclude, that they can be, and have been caused by processes analogous to those in our sealed tubes and digestors. If with the comparatively moderate allowances of pressure, temperature and *time* granted to us, we can in such apparatus bring about the striking results recorded by experimenters in this direction, what may we not suppose to take place in the enormous sealed tube which is represented by deeply-bedded masses of rocks, highly heated for long periods under intense pressure, with water and solutions which cannot escape.

It may be assumed that under such conditions solutions of mineral constituents would be formed of great density, amounting to something like an "aqueous fusion" of the substances involved, and that these solutions could solidify to amorphous and more or less indefinite compounds, or would be capable, under some conditions of cooling, of giving rise to definite minerals.

It seems a not unreasonable supposition that the new substance seen in so many contact-rocks has been formed in this way, and that what we see of it represents various stages of its developments and of its residues; also that the solution supposed would have a most important part in the transformations of the minerals not originally taken up into it.

It would naturally be formed in greatest amount nearest the intruding granite, where temperature would be highest and the heat longest continued. There, also, the conditions of subsequent cooling would usually involve greater length of time and greater opportunity for recrystallization, so that in most cases we should have here least of any indefinite residue, or might often have no such residue at all left over for our observation. In the outer zones of the contacts we should have less of the dense solutions, either formed or, more likely, penetrating from the more intensely affected zones where they were abundant; but as such outer portions would soonest commence to cool again, and cool most rapidly, we should here have a larger proportion of the residues of these solutions left in an undeveloped, or slightly developed, condition.

Comparatively small portions of such solutions reaching these

outer regions would tend to draw together, as little spots and patches, among the ingredients of the otherwise not much affected rock, and would consolidate in this form.

As in contact-regions generally there can frequently be observed anomalous phenomena, such as strata, or portions of strata, which have been much less or much more affected than others close to them, without our being able to explain the fact, so we have anomalies in the behaviour of these supposed dense solutions, and an inner zone may sometimes show a large amount of the less developed residual matter, as in the case of the hornfels mentioned above from Spitzenberg, and other cases of which I have specimens. A notably good example occurs in one of a series of rocks from the Elbe Valley, in which the large amount of the substance present surrounds and envelops the minerals in such a manner that a glance at a section is enough to convince the observer that it was present as a fluid medium when these minerals crystallized.

If we look at all the changes which have taken place in a well developed contact rock, like that at Shap for instance, it seems absolutely necessary, in order to explain what we see, to assume that almost all the original ingredients have been taken up into some sort of solution and completely newly formed out of it. It is not necessary to assume that they were at any one time all in solution at once, or even a very large portion of them.

A solution, or solutions, would be formed of those ingredients of the rock which were most readily acted upon by the imprisoned liquids, and the perhaps only relatively small amount of solution so formed would act as a medium for the slow solution and recrystallization of minerals, just as relatively small amounts of certain solutions and fluxes have been made to act in recorded experiments. The composition of the first solution would not be always the same. It would vary with the varying composition of the slates, etc., acted upon, but probably not in very wide limits, as the *qualitative* composition of most slates is strikingly uniform. The variation might, however, be expected to be sufficient to influence the products which would result from the crystalline development of the solutions. According to my observations the most usual development gives rise to mica in greatest quantity, but felspar and quartz also result in some cases.

Let us, finally, glance at the principal mineral changes which we know to take place in contact-metamorphism, and see what conclusions we seem justified in drawing as to how they have come about, and how these harmonise with the ideas above suggested.

(1) *Rutile.*—By universal testimony we find that in all contact-areas of slates, etc. (whether the intrusive rock is granite or a more basic rock) one of the most unfailing, as well as most sensitive, indications of commencing metamorphism is that the minute "clay slate needles" undergo an alteration by which they decrease in number and increase in size, at the same time that they become blunter in proportion to length and have more definite pyramidal terminations. This occurs so far from the intruding rock that we cannot suppose

any but very moderate thermal or other effects, due to its intrusion, to have acted; and this conclusion is borne out by the very slight effects, if any, which can be seen to have taken place in other particulars. The sedimentary rock being under those conditions of temperature and pressure due to its depth of cover, etc., the intrusion of the igneous rock may have slightly intensified the temperature at these points,—possibly also the pressure, for a time. But this has sufficed to bring about the alteration of the rutiles.

We have already considered the question as to *how* the change is brought about, and simple *solution* of the rutile appears to be the necessary process. The intrusion of igneous rock appears to have given rise to this, and as other effects are absent or so slight, we need not assume anything more than water, or perhaps a weak alkaline solution, to have come into play. The manifold forms in which the dissolved titanic acid may recrystallize have been pointed out, and we may now add brookite as a further extension of this list, R. Beck having observed its occurrence in the rocks of the Elbe Valley contacts, in a manner exactly similar to that of the Anatase at Shap.[1]

(2) *Biotite.*—Perhaps the next mineral change, in degree of sensibility, is the appearance of biotite in the slates undergoing contact-metamorphism, which is also a matter of universal observation. It takes place at considerable distances from the contact, and may be seen already far advanced before the formation of regenerated quartz-mosaic and other minerals is demonstrable.

A large number of slates, etc., contain a good deal of chlorite, which was deposited in them at a period subsequent to their formation as such, by simple infiltration processes. This chlorite is altered into biotite.

This change, like the one last considered, also cannot be explained by *direct* action of raised temperature or pressure. No amount of simple "molecular rearrangement" of chlorite under heat or pressure will make biotite of it. A portion of its water could be removed, as is required; but it has also to take up potash, and here again we must look to solutions, which in this case must contain some alkaline salt.

There are, again, many slates, shales, etc., which are wholly or almost free from chlorite, but which contain a sufficient amount of magnesia to correspond to a good deal of biotite, this magnesia appearing to have entered into combination in the new micaceous minerals existing in the slate, etc. Under contact-action biotite may be, and is, developed in such slates, and this could take place by easily conceivable molecular rearrangements.

Whether it be possible for flakes of chlorite, lying in among flakes

[1] Even this list of changes does not exhaust the number of transformations the titanic acid may undergo. At later stages of the metamorphism it appears that part of it can be taken up into the newly-formed contact-biotite, thus ending up where it began,—combined in dark mica. Such contact-biotite has been shown, by Lang and Jannasch, to contain as much as 3.40 per cent. of titanic acid, and Beck records (*op. cit.*) cases of *decayed* contact-biotite in which rutile has once more been separated out.

of muscovite, to be converted into biotite by direct combinations with those minerals we cannot say. Probably some geologists would not doubt the power of intense pressure to bring this about. We may question whether pressure alone could do this, or anything like it, but when high temperature and water are also considered, acting at the same time, we must at least look on this method of formation as not outside the limits of consideration.

(3) *Newly-formed quartz and felspar.*—We cannot well consider the occurrence of these "regenerated" minerals separately, because though they may not occur together, yet when they do so occur their modes of formation appear to be intimately connected.

The quartz is the more frequent, and, even when felspar occurs, is the more "sensitive," occuring at earlier stages and being often largely developed before any felspar is seen.

It seems obvious that the quartz-grain of the "contact-mosaic" bears no direct relationship to the clastic grain of the original slates, etc. The latter, with its more or less angular outlines, its fluid-cavities, and its practical freedom from enclosures, has disappeared, and in its place we have the round, or in the best-developed mosaics the polygonal, grain, free from fluid cavities, and containing usually numerous microlites, biotite crystals and grains, and other enclosures, these grains of quartz fitting to one another and to the other constituents of the mosaic quite closely and exactly.

It is here still less possible to see how this change can be due to any simple re-formation of each individual grain of quartz,—to its mere recrystallization *in situ*. Neither is it due to any simple addition to its outer portions of any freshly-deposited silica. Looking at these mosaics carefully, it does not seem easy to come to any other conclusion than that the quartz in them, as a whole, has recrystallized out of some sort of solution in which were, forming or already formed, the microlites and other bodies which are now enclosed within the quartz grains.

Many fine-grained slates do not contain any distinguishable grains of quartz at all, and in these, as also in slates where such grains are plentiful, there is a good deal of exceedingly finely-divided quartz or other forms of free silica. It is equally difficult to see how this could be formed up into the larger grains of the mosaic, and charged with enclosures, without a previous re-solution and recrystallization.

Taking now the felspar, where such occurs, all the same considerations apply. The grains in the mosaic have the same characteristics as regards general outlines, enclosures, etc., and it is clear that the quartz and felspar were crystallized *together*, though there is a distinctly greater tendency in the felspar to develop idiomorphic forms.[1]

[1] It should be noted that the "tesselated" or "mosaic" structure is by no means peculiar to the alteration of *sedimentary* rocks. At Shap, for instance, it is very beautifully developed in some of the altered rhyolitic and andesitic ashes in the contact-zone; sometimes it is quartz alone, sometimes quartz and felspar, and sometimes felspar alone which forms these mosaics.

A tesselated structure has been looked upon by some observers as quite specially a result of *dynamic* metamorphism, but this idea can, of course, no longer be enter-

It is to be noted that during the stage of metamorphism which develops the mosaic of quartz, or quartz and felspar, the biotite formed at an earlier, less intense, stage undergoes further alteration. It may be seen (as at Shap) that the earlier biotite is more ragged and indefinite in form, is less dichroic and less bi-refractive than that which exists in the mosaics nearer contact. Whether it is redissolved and recrystallized in part it does not seem possible to decide; but the biotite which is *enclosed* in the quartz and felspar is of much interest, and may give us some indications as to the degree of temperature which prevailed during the processes. In addition to small flakes and more or less definite *crystals*, we see numerous oval grains and little *balls* of biotite, whose forms seem to indicate that they were quite plastic at the time of inclosion, and we may well assume that in these zones there was a condition of aqueous fusion of sufficient intensity to melt, or soften, portions of the biotite.

The interesting question arises as to the mode of origin of this new felspar: What is it made from?

It may, I consider, be stated as a fact that *new* felspar does not exist in any normal slates, no matter how highly developed they are. I have given much time and patience in studying this special point, and have convinced myself that no regeneration of felspar takes place. In the Cornish slates no trace of felspar of any kind is seen, though these are so very highly developed. Rénard records the same absence of it in the very similar Ardennes rocks.

In Welsh slates a few grains are sometimes seen of *clastic* felspar more or less altered, and this is seen in other slates also, but such grains are rare and unevenly disseminated. At Shap, as before stated, no trace of it is seen in the less altered slates, though it is so abundant in the well developed mosaics. We have, therefore, in most cases not to deal with a recrystallization of an already existing mineral, but with the formation of this mineral from other materials. The average and normal slate is composed of the materials which make up the clays with which I dealt in the first part of this paper. The simplest explanation, and indeed perhaps the only one open to us on the evidence in our possession, is that the materials of the mica and the quartz of the slates combine, under the conditions we are supposing, to form felspar. In its decay felspar yields mica and free silica, and it is perfectly simple and easy to comprehend how, under the conditions of temperature pressure, etc., we are supposing, with the intervention of such a dense mineral solution as I have shown cause for believing to exist, the reverse process may take place, and we may have a *partial*

tained. It may be well seen in igneous rocks. Thus, General McMahon shows it to occur in the marginal portions of Dartmoor granite (Q.J.G.S. vol. 49, p. 388), and has previously shown its occurrence in granite of the Himalayas. It is also, as is well known, seen perfectly developed in the groundmass of some quartz-porphyries, not to be distinguished, as to its structure and general appearance, or in anything except its inclusions, from some of the finer-grained mosaics of altered slates. In considering this structure in the contact-metamorphism of slates it is a point of some importance that exactly similar structures can be seen to result during the consolidation of purely igneous magmas.

re-formation of the felspar which originally formed part of the deposits of the slates, but which no longer existed in them as such.

(4) *White mica.*—In some, probably in most, contact-areas a good deal of white mica is newly-formed. It may not be always easy to trace the exact stages of the process. The original slates are usually rich in white mica to begin with, and the recrystallization of the mineral in the earlier stages of contact-metamorphism is not readily distinguishable. But in the more advanced stages we see it more plainly, and find a good deal of mica which from its general appearance and relationship to the other minerals is clearly re-formed, this being also demonstrated frequently, as to larger individuals, by their being more or less charged with quartz-grains, etc., in the same manner as are the biotite-flakes and crystals, and the other newly-formed minerals.

In addition to this mica which appears plainly to have recrystallized in a manner exactly similar to that of the quartz and felspar, we often see also the mica of which I have spoken as appearing by various stages in the newly-formed substance to which so much reference has been made, and which in the fullest form of its development will remain as patches among the mosaic, or as fringes round its component minerals, and may not in all specimens be visibly connected with any residual portions of the substance out of which it originated.

(5) *Cordierite, Andalusite, Cyanite, Sillimanite.*—These are the minerals we may perhaps designate as more specially "contact-minerals," and we may safely say of them that the conditions of their formation, and why sometimes one is formed and sometimes another, are the points as to which we probably know least of all.

As regards cordierite, it appears to stand in a somewhat different position from the rest. It is not a silicate of alumina only, and its formation appears to take place often at a much earlier stage of the metamorphism. It is also a much less stable mineral than the others.

Looking at the composition of cordierite and the mode of its occurrence in these contact-rocks, the most reasonable supposition as to its origin appears to be that when the recrystallizations and rearrangements of the minerals commence, the cordierite, when formed, largely represents the magnesia which is combined in the mica of the slates,—mica which we call sericite and which we have good reasons to regard as muscovite into whose composition magnesia has been taken. As recrystallization of this mica takes place, it will have a tendency to purify itself, and to approach more nearly to the normal muscovite, with more potash and less of other bases; and the magnesia will be available for the formation, more usually of biotite, but under conditions we cannot specify, more or less of cordierite forms also.[1]

[1] It seems desirable to point out that there is risk of sometimes confusing cordierite and felspar in such rocks, where the cordierite occurs as smaller grains and is not a striking constituent. In the books we are warned against mistaking cordierite and quartz; but a similar warning does not seem to be given as regards felspar. As regards quartz the risk does not appear to be great. Where there are several grains

Staurolite may be appropriately mentioned at this point. It is also not a silicate of alumina only, and from its chemical composition may be reasonably supposed to have an origin of somewhat similar nature to that of cordierite.

It does not appear to occur as frequently as the other minerals now being considered; but when it occurs it seems to form in the less intense stages of metamorphism, as for instance in the example studied by Mr. Barrow, to which reference is made below.

As regards the other minerals, the aluminous silicates, it is usually assumed that they represent the "kaoline" of the slates, etc., and there is on the face of it much in favour of this view. If this be so we should expect rocks rich in alkali in proportion to alumina to give little or none of these aluminous silicates during metamorphism, and there are cases where this is borne out, as at Shap for instance. But I do not think that an examination of the analytical evidence in general will show that we can make a rule of this. There are analyses of rocks very rich in andalusite, for instance, which show high percentage of alkali; and copious development of andalusite and felspar may take place together, as is seen in some of the Andlau rocks. At Shap also, we have altered rhyolitic ashes in which there is a great deal of newly-formed felspar, together with andalusite, and an unusually large development of sillimanite. Therefore it would appear as if the formation of these minerals is a more complex question than to depend simply on certain ratios among the chemical constituents of the rocks metamorphosed.

For the rest, looking at their chemical composition and their mode of appearance in our sections, their relationships to other minerals, etc., it would be even more difficult than in other cases to imagine their origination in any other way than by a dissolving-up and complete re-combination of the original materials of the slates, etc.

Concerning the conditions determining *which* of the aluminous minerals shall be formed, we have as yet very little to guide us; but in a paper of exceptional interest, recently read before the Geological Society, Mr. Barrow produces evidence to show that probably difference of temperature is the principal controlling element. In his work on a contact-region in Scotland, Mr. Barrow has observed that sillimanite, cyanite, and staurolite occur in the order named as we recede from the actual contact, and he suggests that the occurrence of each mineral coincides with a zone of temperature. He correlates this observation with the experimental

of cordierite in a slide it will nearly always be possible to prove that we have a *biaxal* mineral before us, and therefore not quartz. But in a thin section it may often happen that we cannot say whether the biaxal grain is cordierite or felspar, simply by its optic examination. Felspar grains, without any cleavages or definite forms, occur in these rocks. The refraction and bi refraction are not sufficiently different to serve as guides when cut thin, and in many of the best occurrences of cordierite in contact-slates the dichroism of the mineral, and the "halos" round its enclosures, are not discernible at all in most grains. Enclosures, etc., may aid in discrimination, and usually do so; but I have satisfied myself that the determination is often a difficult one, and think that there is considerable chance of cordierite being overlooked in some cases in consequence.

work of Vernadsky, in which it was shown that when cyanite is heated to 1300°—1400° C. it is altered to sillimanite.

Mr. Barrow has made it appear very probable that in the hotter zones of contact sillimanite will be formed, that cyanite will take its place when a certain limit of lower temperature is reached, and staurolite will occur in the still cooler outer zone. No doubt these observations of Mr. Barrow in this particular district will cause the point to be carefully studied elsewhere.

Mr. Barrow further infers from Vernadsky's experiment that we may conclude that in the "sillimanite zone" of contact-rocks there has been a temperature of 1300°—1400° C. or over. This seems rather straining the matter; and certainly attempts in the past to draw conclusions as to rock-temperatures from experiments on minerals in the laboratory have not been so happy in their results as to encourage repetition, however tempting a system of "recording pyrometers" in the rocks may appear. It does not seem in the least necessarily to follow from Vernadsky's experiment, either that the sillimanite in the rocks was produced from cyanite, or that the formation of sillimanite *instead of* cyanite in the hotter zones indicates that the temperature was 1300°—1400° C. or that there need be any definite relationship whatever between the temperature at which it forms in these rocks and that at which it may be produced, from another mineral, in a laboratory-furnace.

If contact-metamorphism be due entirely to the thermal effects of the intrusive rock, as now seems usually to be believed, we should expect to see these effects always the same, in kind, on the same variety of rocks undergoing metamorphism, and the alterations due to a dolerite should not differ from those due to a granite. In the main this seems to be borne out, but there are some important points which still call for a good deal of attention.

I may state that so far as my own observations go, in which I am still engaged, there is, for instance, a formation of the same substance, due to the same causes, as I have described above; but it is present in less amount, and a larger proportion of it remains in the amorphous, or slightly developed, state. Also there is much less formation of "mosaics" and these again much less developed. These facts can be easily understood by having regard to the relative smallness of the masses of igneous rock acting in the observed occurrences, and the consequent less *time* during which recrystallization would be able to go on.

It does not appear that isotropic substance is much mentioned by observers of altered slates, etc., at *granite*-contacts; but it is frequently spoken of where the intrusive rock has been "diabase."

The most striking difference, however, between acid and basic contacts, so to speak, lies in the fact so often recorded, and backed up by so much evidence, microscopic and chemical, that there is a transfer of material from the intruding basic rock to the slates, etc.; a transfer which is large in proportion to the relatively small masses of igneous rock concerned in it. It is shown by the increase of *soda* in the altered rocks, chemically considered, this increase being

again represented mineralogically by the formation of albite and probably other soda-bearing felspars.

The transfer has been disputed by some observers, but the evidence is too strong to be denied, even if it may be proved that there are exceptions. It has also been suggested that the transfer has not taken place at the time of intrusion,—that it is not a contact-phenomenon at all,—but is due to later processes connected with the decay of the igneous rock. This is a point still calling for investigation.

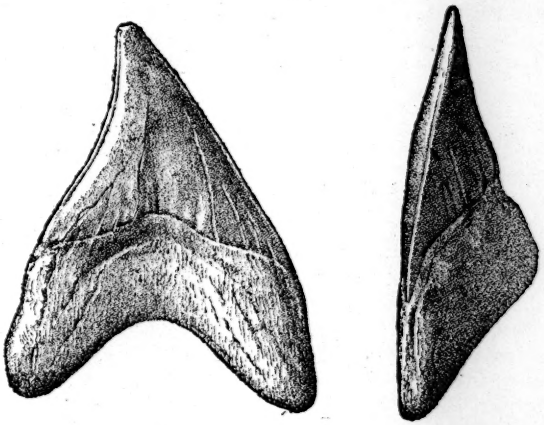
I hope later on to deal with the subject of these basic contacts, as I am at present engaged in examining a large series of such rocks.

All that I need here remark is that I have fully satisfied myself of the transfer of soda, and of the presence in some cases of large amounts of isotropic material due to contact-action.

IV.—Note on a Tooth of *Oxyrhiña* from the Red Crag of Suffolk.

By Arthur Smith Woodward, F.L.S., F.G.S.

ALL the Selachian teeth hitherto obtained from the English Crags referable to the genus *Oxyrhina* are much compressed antero-posteriorly, and are thus slender in proportion to their size. They are now commonly regarded as representing a single extinct species, *Oxyrhina hastalis* of Agassiz,[1] and the same form of dentition



A B

Tooth of *Oxyrhina crassa*, Ag., natural size, from the external (A) and lateral (B) aspects; Red Crag, Hemley Hall, near Woodbridge, Suffolk.
[Collection of T. W. Reader, Esq., F.G.S.]

is abundant in the Pliocene of Italy, besides occurring in other Tertiary deposits in various parts of the world. In Italy and Belgium, however, these comparatively slender teeth are accompanied by a few

[1] Smith Woodward, "Catal. Foss. Fishes, B. M.," pt. i. p. 385; E. T. Newton, "Verteb. Pliocene Dep. Britain" (Mem. Geol. Surv. 1891), p. 106, pl. ix. fig. 15.

others of the same genus of very robust proportions; and some of these have received the names of *O. Benedeni*,[1] *O. gibbosissima*, and *O. Forestii*,[2] while others have been identified with *O. crassa* and *O. quadrans*.[3] So far as the present writer can judge, none of these robust teeth are capable of being satisfactorily distinguished from the species *O. crassa* of Agassiz, originally described from the Miocene of the Rhine Valley;[4] and it is under the last-mentioned name that they are recorded in the British Museum Catalogue.

It is now of interest to announce that the same form of robust tooth has lately been obtained from the English Pliocene. The specimen was discovered by Mr. T. W. Reader, F.G.S., in the Red Crag of Hemley Hall, near Woodbridge, and it is shown of the natural size from the external and lateral aspects in the accompanying figures. As indicated by its shape, the tooth must have occupied a postero-lateral position in the mouth, probably in the upper jaw; and a specimen most closely approaching it is described by Lawley from the Pliocene of Italy under the name of *Oxyrhina quadrans*.[5]

In general aspect, of course, the new fossil is at first sight suggestive of a tooth of the so-called *Otodus obliquus*, wanting the lateral denticles. The specimen, however, is quite unabraded and has not the appearance of a derived fossil; while it is certain that the absence of denticles is not the result of fracture. It may be that some such robust teeth are abnormal examples from the dentition of *Otodus obliquus*; but, in default of all proof of this possibility, it seems advisable to retain the nomenclature here adopted.

V.—An Ancient Glacial Shore.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

In a cutting of the Seacombe Branch of the Wirral Railway at the present moment is to be seen a deposit which cannot be other than a glacial shore.[6] It is about 18 inches thick, covered by a bed of Boulder-clay some 8 feet thick, and has been exposed by the cutting for a distance of 16 chains running south-east and north-west, to the south-east of the point of intersection of the Railway with Poulton Road. The rise is 16 feet in this distance at a regular up-grade towards Poulton Road, and the average level about 60 feet above O.D. Transversely to the Railway it is about level, and over the whole of the area—1056 feet by 30 feet=3520 superficial yards—the deposit occurred and was excavated by the steam navvy. The bed is composed of pretty clean sand with some small gravel, and is crowded with shell fragments in all stages of decay. It is precisely like a modern beach in constitution, extent and slope, but what renders the fact more certain is the

[1] H. Le Hon, "Prélim. Mém. Poiss. Tert. Belg." (1871), p. 6, with figure.
[2] R. Lawley, "Nuovi Studi Pesci, etc., Colline Toscane" (1876), p. 31.
[3] R. Lawley, *ibid.* and "Studi Comp. Pesci foss. coi viv. generi *Carcharodon Oxyrhina*, e *Galeocerdo*" (1881), p. 112, pl. iv. (*Oxyrhina*), fig. 2.
[4] L. Agassiz, "Rech. Poiss. Foss." vol. iii. (1843), p. 283, pl. xxxvii. fig. 16.
[5] *Op. cit.* 1881, pl. iv. (*Oxyrhina*), fig. 2.
[6] I am indebted to Mr. Henry Beasley, the Hon. Sec. of the Liverpool Geological Society, for calling my attention to this interesting bed.

great quantity of clay balls or boulders mixed with the sand. These balls are covered over their surface with small gravel, shells and sand, picked up as they rolled about on the beach, just like the mud balls we find on the shore at Crosby at the present day. On being cut into with a knife these clay balls are seen to be formed of ordinary compact brown Boulder-clay, and they are pretty hard. The contractor, Mr. Davies, who is much interested in the geology of the cutting, tells me that these clay balls are found all over the area in great profusion, and as far as I tested the bed, which I did in at least half-a-dozen places, I found the statement correct. He also informed me that the bed is underlain by silt, but it has not been tested more than a few feet deep. I picked up and brought away about twenty clay balls varying in size from 3 inches down to $\frac{3}{4}$ inch diameter, some of them being spherical and others ellipsoidal in form.

These balls or boulders can, I believe, only be found on the shores of tidal seas, where they get partially dried during the recession of the water twice in 24 hours, and more dried at neaps. If they were constantly immersed they would get dissolved.

In the GEOLOGICAL MAGAZINE for 1878, p. 571, I described the formation of clay boulders from the Estuarine clay on the Crosby shore, and shortly afterwards was informed by the late Mr. Binney, F.R.S., that he had found similar boulders in the Boulder-clay in a railway cutting near Crumpsall[1] 207 feet above the sea-level. But such boulders are not only made from stiff clay; the recent mud deposits yield them also, and, as I said before, they are quite a common phenomenon on our shore. I have seen a few in drift on other occasions, but in nothing like the regularity and profusion shown in the instance I am describing.

Glacialists who are satisfied with no explanation of drift phenomena which does not ascribe everything to land-ice continually ask those of more moderate views who still believe the sea had a considerable share in the work to show them shore-lines. With this object I forward these lines, and there is no doubt the ancient beach is much more extensive than the portion touched by the excavation.

I may add that glacial striæ bearing N. 25° W. are to be seen on the Keuper Sandstone when bared of Boulder-clay, in the same cutting, but at a higher level and more to the north-west.

POSTSCRIPT, *December 6th.*—Since the above was written the excavations from Poulton Road to Mill Lane have disclosed a continuation of the beach a fresh distance of 10 chains. At this western extremity the clay boulders occur, but not in such profusion, and the sand increases in thickness. Allowing for the curve in the line, the plane of the beach is continued at the same slope. The laminations of the bed south-east of Poulton Road are now very apparent, and thin beds of small clay balls are intercalated in the laminæ.—T. M. R.

[1] See "On Boulders of Clay from the Drift" by E. W. Binney, Proc. Lit. and Phil. Soc. of Manchester, 1879, p. 40.

VI.—Post-Glacial Man in Britain.

By William Shone, F.G.S.

THE relative position of post-Glacial Man to post-Glacial geology has been a rather neglected field of research. This borderland between the domains of the Archæologist and the Geologist appears to have been treated as neutral ground, yet entombed in it are the relics of Neolithic Man and the first evidences of the dawn of civilization. It may be alleged that the splendid results of cave exploration have given us a better idea of man's evolution from a savage to a civilized existence than could have been obtained from any other source. Whilst this must be admitted, cave research can furnish very little evidence of the great physical changes which went on outside such abodes. If for instance man can be proved to have been an inhabitant of Western Europe during the Glacial epoch, the gradual change of the climate from frigid to temperate may have had a powerful influence in modifying his habits and thereby assisting his development from the state of a rude savage to that of a civilized man. Deposits in caverns aid very little in this work. They are for the most part choked-up subterranean water-courses, and it follows that any deposits found therein may have been subjected to much disturbance. The most slender evidence derived from cave deposits is even by such distinguished geologists as Prof. Hughes and Prof. Boyd-Dawkins thought quite sufficient to determine the momentous question whether Palæolithic Man was Glacial or post-Glacial. Prof. Boyd-Dawkins decides the matter in his "Early Man in Britain," p. 192, in the following very summary manner:—

"Palæolithic man has left no traces of his presence in the caves of Castleton and Matlock. They have, however, been met with in several caverns in Wales, such as those of Pembrokeshire and Monmouthshire in the south, and in that of Pont Newydd, near St. Asaph, in North Wales. In the latter a human molar tooth has been found, as well as a *quartzite implement and rude splinters and chips of quartzite, of the same type as those of the red sand and in the caves of Cresswell. The pebbles of which these are made have been obtained from the Glacial deposits in the neighbourhood. We may therefore conclude with Professor Hughes, that the Palæolithic hunter was here after the district was forsaken by the glaciers and the sea, or in other words, in post-Glacial times, as in the parallel case offered by the river-deposits of Bedford and Hoxne. It must also be remarked that the leptorhine Rhinoceros and the Hippopotamus, as well as the straight-tusked Elephant (*E. antiquus*), Bear, Bison, Reindeer and Horse, are found with the quartzite implements in the Pont Newydd cave, which may therefore be classified with those of Yorkshire and the lower strata in Mother Grundy's Parlour."

Mr. Morton, F.G.S. (Geology of the Country around Liverpool, second edition, pp. 188, 189) makes the following comments upon the passage: "Professor Boyd-Dawkins, F.R.S., objects to the Pont

Newydd caves being pre-Glacial, on the ground that stone implements were found in them made from rock which occurs as boulders in the Drift in the neighbourhood; but it seems quite as possible that man may have obtained the stone from its original locality, or from moraines in the early period before the district was submerged, as it had been brought near to the cave in the form of boulders." Mr. Morton's conclusions are further strengthened by the occurrence of veins of quartzite in the neighbouring Wenlock Shale of the Moel Fammau range. Such a suspicion being possible at once destroys our confidence in the assumption that the quartzite implements of Pont Newydd prove Palæolithic Man to be post-Glacial. Then follows the important statement by Professor Boyd-Dawkins, viz.: "The presence of the leptorhine Rhinoceros, Hippopotamus, and straight-tusked Elephant, probably marks the earliest phase of the occupation of the caves of Europe by the Palæolithic hunter."

If Britain were inhabited by this early race of Palæolithic hunters they must have traversed large areas of the surrounding country in search of food. In the excitement of the chase it is inconceivable that they should not have left many a lost weapon, which would to-day testify to their existence in post-Glacial times. Taking England from the Midlands to Berwick-on-Tweed, was ever country so delved to make roads, harbours, mines, canals, railways, and great towns and cities, yet no trace of this Palæolithic hunter or of his contemporaries "the leptorhine Rhinoceros, Hippopotamus, and straight-tusked Elephant," has ever been found over this area upon a post-Glacial surface or in post-Glacial strata.

Neolithic Man.

How different in the case of Neolithic Man; his relics are spread far and wide over the land. A little careful study of the geographical and topographical distribution of his relics, as recorded in Sir John Evans's "Ancient Stone Implements of Britain," will soon afford ample proof. Neolithic Man belongs to the surface period. On the Yorkshire Wolds his flint implements are scattered in profusion, occuring in a foot of soil resting upon Chalk. Wherefore the absence of the quartzite or flint implements of Palæolithic Man, if he be post-Glacial? Again, if we search the Western shores, we find the weapons of Neolithic Man, as at Delamere, Beeston, and Tarporley in Cheshire, upon the surface of the Glacial drift. Any trace of Palæolithic Man is absolutely unknown. If we examine the extensive low-lying plains, bordering the coast-lines of Cheshire and Lancashire, the submerged peat and forest beds of these counties have never yielded the slightest clue of Palæolithic Man or of the Mammalia characteristic of the Palæolithic age.

If, over that portion of Britain which was covered by the Glacial Drift, Neolithic Man was post-Glacial, and early Palæolithic Man of Pont Newydd pre-Glacial, the Glacial Drift must fill the gap between. In that case the Drift will be the equivalent of the various gradations of Palæolithic Man in the driftless areas of Belgium and France. There are two points which would appear

to strengthen this conclusion: the negative one, viz. the absence of any evidence of Palæolithic Man over the areas covered by the Glacial Drift; and the positive evidence of the amelioration of the climate of Western Europe at the close of the Glacial epoch, corresponding to the amelioration of climate which characterized the end of the Palæolithic age and the advent of Neolithic Man. The retreat of the Boreal Mollusca northwards at the close of the deposition of the Drift is a very significant fact if it be considered in conjunction with the dispersion of the Mammalia northwards and Alpwards at the termination of the Palæolithic age.

In considering the relations of Britain to the events of the Glacial epoch, it should be borne in mind that our Island was situated on the confines of that portion of the Northern Hemisphere which suffered glaciation. It was one of the last places the ice-sheet reached, and one of the first from which it retreated. The supposed great time required for the formation of the Glacial Drift and the post-Glacial deposits has blocked the way to any successful attempt to synchronize the Drift with the older river and cave deposits, containing the relics of Palæolithic Man and his Mammalian contemporaries. There are, however, no internal evidences in the Drift deposits indicative of any great antiquity. We frequently find them resting upon glaciated surfaces so perfectly polished, and with delicate striæ so exquisitely preserved, that it might have been but yesterday that the glacier which caused them had retreated, and not, as some affirm it to have been, thousands of years ago. Then, if we examine the Boulder-clay we meet with Foraminifera embedded in it, yet despite their long emtombment their shells show no signs of decay.

The Drift rarely exceeds 300 feet in thickness. If it were formed at the rate of a quarter of an inch per annum, a little over 15,000 years would suffice for its accumulation.

We possess, of course, no geological data for the foregoing or any other geological calculation of the measure of the duration of the time represented by the Glacial Drift. Therefore, no reasonable objection on the ground of the great lapse of time required for the formation of Glacial and post-Glacial strata can be taken against synchronizing the Palæolithic age with the Glacial Drift, and Neolithic Man with post-Glacial times.

* Query: "felstone," for which see Prof. Hughes' most interesting paper upon the "Drifts of the Vale of Clwyd" (Q.J.G.S. vol. xliii. p. 107). It is quite immaterial, however, to the argument, whether the implements found in the "Pont Newydd" cave were composed of "quartzite" or "felstone," as both rocks would have been equally accessible.

VII.—The True Horizon of the Mammoth

By Mark Stirrup, F.G.S.

IN the abstract of the proceedings of the meeting, on November 8th, of the Geological Society of London, I notice that on the reading of Dr. G. M. Dawson's "Notes on the occurrence of

Mammoth-remains in North-West America" the author cites the presence of Mammoth bones in a layer of clay *resting on* the "ground-ice" formation of the northern coast of Alaska and other areas.

I drew attention to this position of the Mammoth bones *above* the solid ice both in North Siberia and Alaska, as proved by several explorers, in my paper on "The True Horizon of the Mammoth" (GEOL. MAG., No. 345, p. 107, March, 1893), in which I claimed for the Mammoth an existence long after the period assigned for its extinction by Sir Henry H. Howorth.

I see that Sir Henry, in the discussion of the paper, very naturally disagreed with the conclusion of Dr. Dawson as to the age of what is called by American geologists the "ground-ice" formation, and was of opinion "that this ice has accumulated since the beds were laid down in which the Mammoth-remains occur, and that the ice was not there when the Mammoth roamed about in the forests where he and his companions lived."

Furthermore, he is reported to have said that "humus and soil cannot accumulate upon ice, except as a moraine," both of which statements are controverted by the explorations of recent and competent observers who have examined these regions.

In support of my contention I need only refer Sir Henry to the explorations of Dr. W. H. Dall in the Alaskan regions (which I quoted in my previous paper), and to the evidence of other observers which Dr. Dall summarizes in the Bulletin of the United States Geological Survey, No. 84, pp. 260–267, recently issued. Dr. Dall, speaking of the "ground-ice" formation, says "a remarkable formation has been recognized in many places in the northern part of Alaska, in which solid beds of ice of considerable thickness perform the functions of rock strata and are covered by beds of blue clay containing numerous remains of Pleistocene mammals, or by beds of alluvium which sustain a layer of turf, with ordinary profuse herbage of the region, or even small thickets of birch, alder and other small Arctic trees."

These mammalian remains include, among others, tusks, teeth and bones of the Mammoth, *E. primigenius*, bones of *Bison antiquus*, and the Musk Ox. The mode of origin of this ground-ice formation is undoubtedly difficult of explanation, but its position *beneath* the Mammoth-bearing beds is uniformly the same, whether in the cliffs of the coast or in those bordering the Alaskan rivers.

Dr. Dall, referring to the stratigraphical position and mode of accumulation of the bones, says, "that all the circumstances point toward the view that the ice *preceded* and subsequently *co-existed* with animals whose remains are now found in its vicinity."

Lieut. J. C. Cantwell, United States Revenue Marine, reporting on the Kowak river ice-cliffs discovered by him in 1884, says "they are composed of solid ice, covered by a layer of dark-coloured earth, uniformly about 6 feet thick, the whole rising to the height of 15 to 150 feet, with trees 4 to 8 inches in diameter growing on the surface."

He goes on to say, "quantities of Mammoth tusks were observed in this clay and its débris, where undermined by the stream. These clays were doubtless of the same age as those in which the Mammoth-remains are found at Elephant Point, *over* the ice-cliffs.

In consideration for your valuable space, I refrain from quoting further evidence as to the superposition of the Mammoth-beds over the solid ice stratum.

The question of the food supply necessary to the existence of the extinct herbivorous mammals which once roamed those arctic plains, seems to be settled by the actual existence of an abundant, though arctic, flora in these apparently inhospitable wastes.

Travellers speak of the dense thickets of willow, through which they have to push their way, and also of the luxuriant growth of grass covering the peaty or clayey soil.

Moreover, Dr. Dall mentions, singular as it may seem, the fact of dwarf birches, alders, 7 or 8 feet high, with stems 3 inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, growing with the roots less than a foot from perpetual solid ice.

Sir Henry Howorth's explanation of the mode of formation of these massive beds of ice by filtration of water through the soil is certainly inconsistent with the structure and purity of the ice. The ice, 50 to 150 feet thick and upwards, where exposed in sections of the cliffs, is described by several observers as pure, clear ice. Dr. Dall says "the ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial."

The facts that I have thus briefly cited are wholly opposed to Sir Henry Howorth's assumption that the present is the coldest period known in recent geological times in Siberia and Alaska, and further, I contend that the elaborate arguments and conclusions embodied in his "Mammoth and the Flood" and his "Glacial Nightmare," so far as they rest on his assumption of the pre-Glacial age of the Mammoth, receive no support from the evidence derivable from North Siberia and Alaska.

REVIEWS.

I.—Zur Histologie der Faltenzähne paläozoischer Stegocephalen.

On the Histology of the plicated (folded) teeth of Stegocephali. By H. Credner. Abhandl. der mathemat.-physischen Classe der K. Sächsischen Ges. der Wissenschaften. Band xx. No. iv. Mit vier Tafeln und fünf Textfiguren. Royal 8vo. pp. 477-552. (Leipzig, 1893.)

WITHIN the last thirteen years Professor Credner has made us acquainted with the Stegocephali and Saurians of the Permian limestone near Dresden, from the smallest salamandrine

Branchiosauri up to the huge *Sclerocephalus* with almost inch-long teeth.[1] Their variety in external appearance, as well as in the extreme specialization of their skeleton, in which they diverge in a more or less degree towards the Reptilia, is so extraordinary that we have to look for their progenitors in still more remote periods. On the other hand, the less varied teeth, studied in the present Memoir on the dentition of *Sclerocephalus labyrinthicus*, Gein. sp., are proved, by their histological details, to be ultimately the homologues of the minute teeth of certain ichthyous scales, and at the same time throw an unexpected light in an opposite direction, inasmuch as we begin to have a clue as to the primitive form and the evolution of the Vertebrate tooth in general.

In the first chapter, the dentigerous bones of the buccal cavity (viz. the premaxilla, maxilla and mandible the anterior alæ of the pterygoid and the palatine), as well as almost all the bones of the skeleton, are shown by their characteristic structure to be *dermal bones*, nearly related to the *Ganoid* scales. The dermal bones of the cranium, particularly, prove to be the exact homologues of these last, as they are composed of the same three strata: (1) a thin basal stratum of calcareous lamellæ (*Basalschicht von Kalklamellen*), followed by (2) a much thicker stratum of osseous tissue, which is distinguished chiefly from that of the enchondral bones of the rest of the skeleton (including the quadrate and articular of the mandibular articulation) by a dense system of blood-vessels (*Haversische Canäle* of Klaatsch), extending in a horizontal direction, according to the plane of the greatest extension of the bone. (3) The minute external covering of the osseous plates is formed by a delicate layer of *Osteodentine*, which, in the dentigerous bones, continues directly into the dentine cones of the small cuspidate teeth.

The same homology exists between the minute palatine teeth of *Sclerocephalus* and the small teeth of the *Ganoid* scales; both are cuspidate dentine cones, provided with a delicate enamel cap and a large pulp; their basal expansions are fused into the layer composed of a modification of dentine (*Ganoin*), which covers the second stratum above described.

The histological structure of the large jaw teeth is closely investigated on ten transverse sections, and leads the author to the conclusion that these plicated teeth (*Faltenzähne*) of *Sclerocephalus* owe their origin to the coalescence of the elements (*Anlagen*) of numerous most primitive teeth, similar in shape to those on the palatine bones; whereas the cement-ridges (*Cementleisten*) of the jawbones are formed by a fusion of the basal layers of the jaw teeth.

All the larger teeth, uni- or multi-cuspidate, of the *Eotetrapoda*, and consequently likewise of the higher Vertebrates generally, are thus shown to be *polysynthetic*, viz. produced by a fusion of the pulps of numerous tooth-germs (*Zahnanlagen*), so that they do not represent primitive, but phylogenetically acquired structures.

[1] H. Credner, Die Stegocephalen und Saurier aus dem Rothliegenden des Plauenschen Grundes bei Dresden, Part I–X (Zeitschr. d. Deut. geolog. Gesellschaft, 1881–1893).—H. Credner, Die Urvierfüssler (Eotetrapoda) des Sächsischen Rothliegenden. Berlin, 1891, etc.

To the above modification of the *Concrescence* Theory of Kükenthal and Röse cannot be applied the reproach that "it comes from a one-sided Morphology which regards only the wonderful, though mutilated, chapters of Embryology when the untorn pages of Palæontology are at hand."[1]

II.—Ueber die Gliederung der Flötzformationen Helgolands. Von W. Dames. Sitzungsber. der k. preuss. Akad. d. Wiss. zu Berlin, 1893. pp. 1019–1039.

On the Divisions of the Stratified Formations of Heligoland. By Prof. Dr. W. Dames.

IT is quite natural that the little rocky islet of Heligoland, lately transferred from the British to the German Empire, should have been examined by its new possessors with that warm interest which generally accompanies recently acquired ownership, whether by persons or by nationalities. From a geological point of view the rocks of this islet had been considered to show a pronounced relationship to those of the English coast on the other side of the North Sea, but Prof. Dames, who has spent several weeks this last Autumn in studying its geology, maintains in the present paper, and we think successfully, that they bear the closest resemblance to those of Schleswig Holstein and other areas in North Germany, and consequently that Heligoland is but an advanced post of German territory, with which, geologically, it has had an almost unbroken connection since the close of the Palæozoic period.

Hitherto the rocks of Heligoland have been referred to the Triassic, Jurassic and Cretaceous formations, but Professor Dames states that Jurassic strata are absent altogether. The lowest beds on the main island consist of reddish-brown, thick-bedded calcareous clays, with traces of copper ores, which are closely similar, petrologically, to the strata of Zechstein age in Schleswig Holstein, and to those on the same horizon on the flanks of the Harz Mountains. Conformably overlying the Zechstein on the main island are red and green speckled clays, sandstones and dolomites, considered of Lower Bunter age—in these a characteristic rib of a Triassic saurian has been found. The Middle and Upper Bunter beds probably come in beneath the North Sea, between the main island and the Wite Klif. This latter is of a yellowish clayey limestone or dolomite, containing mollusca characteristic of the Lower Muschelkalk. The Middle and Upper divisions are represented by beds of gypsum and glauconitic limestones and dolomites.

The rocks succeeding the Upper Muschelkalk dolomites contain fossils of Lower Cretaceous age similar to those of the Speeton Clay of Yorkshire and of Simbirsk, in Russia, and the following zones have been recognized by the author in the so-called Töck beds:

1. Zone of *Belemnites pistilliformis*, with *Exogyra Couloni* and *Pecten crassitesta*, belonging to the Neocomian.

2. Zone of *Belemnites brunsvicensis*, with large undescribed species of *Crioceras*.

[1] See American Journal of Science, December, 1893, p. 448.

3. Zone of *Belemnites fusiformis* and *Terebratula sella*. Nos. 2 and 3 are Aptian.

4. Zone of *Belemnites minimus*.

5. Zone of *Schlönbachia inflata*. Nos. 4 and 5 belong to the Upper Gault; the Middle Gault seems to be absent.

The rocks referred to the Upper Cretaceous are only exposed at ebb-tides; they have hitherto been considered only to represent the Upper Chalk with flints, but Dr. Dames has ascertained from the fossils, partly in the rocks *in situ*, partly in the boulders, that the Cenomanian is present with *Terebratula depressa*; and of Turonian age there is a reddish chalk with *Inoceramus mytiloides*; a white chalk with flints containing *Inoceramus Brogniarti*; and a yellow chalk with *Scaphites Geinitzi* and *Holaster planus*. Of the Senonian, three zones are represented, viz. that of *Inoceramus lobatus*, of *Belemnitella quadrata*, and of *B. mucronata*. No Tertiary strata are present.

The observations of Dr. Dames have very materially increased our knowledge of the geology of this interesting islet, and we are glad to note that he has promised to bring out a detailed description of the fossils present in its rocks, which will be quite as highly appreciated by British as by German geologists.

G. J. H.

III.—Memoirs of the Geological Survey of the United Kingdom; The Jurassic Rocks of Britain. Vol. III. The Lias of England and Wales (Yorkshire excepted). By Horace B. Woodward, F.G.S., President of the Geologists' Association. 8vo. pp. xii. and 399, with a Map and 89 Woodcut Illustrations. (London: Kegan Paul, Trench, Trübner, and Co., Ld., 1893.) Price 7*s*. 6*d*.

In the Geological Magazine for September, 1893, pp. 415–421, we gave a notice of volumes I. and II. of this Memoir dealing with the Jurassic Rocks of Yorkshire, by C. Fox-Strangways, F.G.S.; the present volume, comprising the Lias of England and Wales, by Horace B. Woodward, F.G.S., is the first instalment of his work and forms an important and acceptable addition to our knowledge of the Jurassic rocks of Britain, south of the Humber.

"The present volume," says Sir Archibald Geikie, "has been prepared entirely by Mr. Woodward. His training in the field-work of the Survey had made him intimately acquainted with the Jurassic rocks, for, between the years 1867 and 1874, he was engaged under Mr. Bristow, the late Director for England and Wales, in re-surveying the Secondary formations in the south-west of England and the south of Wales."

In the introduction the author treats of the term Jurassic, and of the extent of these rocks in Britain, with their relation to the formations above and below them. In dealing with the history of the Jurassic rocks the place of honour is naturally given to William Smith, who, in his earlier work, was specially identified with the Oolitic rocks of the south-west of England, and many of whose names are still re-

tained to designate their subdivisions. A table of these is given, and also one showing the principal subdivisions of the Jurassic rocks from Dorsetshire to Lincolnshire. The sequence of the rocks, their changes, with their stratigraphical and palæontological subdivisions, their fauna and flora, and characteristic fossils are discussed.

Mr. Horace Woodward then gives a general account of the Lias formation and its organic remains, illustrated by numerous figures of fossils. The opinions of Dr. Sorby and Mr. J. J. H. Teall on the microscopic structure of the Lias are also quoted. A table is given of the principal zones in the Liassic rocks with the names of the Ammonites by which they are characterized. Attention is also given to the origin of the limestones, many of which are considered to be largely of sedimentary origin.

Here, in the text, and also in the Catalogue of Liassic fossils at the end of the Memoir (see pp. 330 to 378), they are given "under the generic name *Ammonites*, because confusion must have arisen if any attempt had been made to employ the subgeneric names. These names, indeed, may be of service to the specialist who confines his attention to the Ammonites, but they are of biological rather than geological importance. Some of the names, indeed, have been changed again and again since this Memoir was commenced, and many of the species, unfortunately, are so split up that the multitude of names is simply bewildering, and they become of little or no service to the stratigraphical geologist. In some cases the same specific name has been applied to *mutations* of different subgenera of Ammonites! a course much to be deprecated, for it is likely that, if accepted as new *species*, the names will eventually be replaced by others."

The author then gives a general description of the Lower Lias, its zones, organic remains, and characteristic fossils, with details of the area over which it occurs, from the coast of Dorsetshire to the Mendip Hills, together with sections along the coast and inland. Other areas recorded are Harptree and Chewton Mendip, Radstock, Keynsham, Bath, Bristol, Westbury-on-Severn, Gloucester, Cheltenham and Tewkesbury. Thence we pass from Evesham to Stratford-on-Avon, Banbury, Rugby, Market Harborough, Barrow-on-Soar, the Vale of Belvoir, Lincoln, Frodingham, Shropshire and Cheshire, and as far as Cumberland, these latter localities possessing "outliers" of the basement beds of the Lower Lias.

The Middle Lias is treated in a similar manner with its zones of *Ammonites spinatus* and *margaritatus*. Figures are also given of various characteristic Middle Lias fossils, with a list of all the organic remains. Then follow local details of the areas over which the Middle Lias extends, in Dorset, Somerset, Gloucester, Oxford, Northampton, Warwick, Leicester, Rutland, Lincoln, and Shropshire.

The Upper Lias, with its zones and characteristic remains, is dealt with as in the preceding divisions, including the topographical area over which it extends. Many new facts are recorded, especially with reference to the Lias of Lyme Regis, to that of South Wales and of Shropshire. The record of a new boring at Mickleton in Gloucestershire, affords evidence that there we have the greatest known thickness of Lias in this country—no less than 1,360 feet.

The chapters on economic geology, treating of Lime and Cement, of Artificial Stone and of Building Stone, Ornamental Marble, of Iron Ore, etc., of Agriculture, Soils, and Water Supply will be read with interest by all those who, as landed proprietors, have a stake in the prosperity of the areas embraced in this Memoir. The Chalybeate Springs of Bath, Cheltenham, and the surrounding country are extremely numerous and many of them of great historical antiquity and virtue.

The fauna of the Lias formation is one of the richest of the British Islands, not only in Flying, Walking, and Swimming Reptiles, but in Fishes and Mollusca; and especially in that remarkable group, the Cephalopoda, by aid of which the various zones of the Lias have long been characterized, the Brachiopoda, Crustacea, Worms, Echinodermata, Corals, and Foraminifera are also well represented, whilst remains of Plants, numerous Insects, Flying Pterodactyls, Dinosaurs, and Crocodiles proclaim the presence of a contiguous continent, the shores of which were washed by the Liassic seas.

Owing to the inferior quality of the paper on which it is printed, this valuable Memoir is presented to the public under great disadvantage; for, notwithstanding the fact that numerous illustrations have been lent to adorn its pages, they are mostly so poorly printed as to fail to express clearly the objects which the artist has drawn. This censure on the printing in no wise detracts the vast amount of arduous scientific labour, the results of years of patient field-work by Mr. Woodward, which this Memoir has involved; nor must we omit to commend the admirable list of fossils, with their respective horizons, occupying just 50 pages of small print, drawn up by the author with the assistance of his colleagues, Messrs. Sharman and Newton. Unfortunately this catalogue does not include all the Liassic fossils of England and Wales, because the species from Yorkshire are given in the Memoir by Mr. Fox-Strangways (above referred to), and only those Yorkshire fossils which occur south of the Humber are mentioned in Mr. Woodward's list.

To obtain a full record of the Liassic fossils of England and Wales, it will be necessary, therefore, to combine the catalogues given by Mr. Fox-Strangways with that contained in the present volume. Surely this might have been done by the officers of the Survey—by mutual agreement—and so the public-at-large, or at least the scientific public, instead of grumbling, would have had reason to laud and magnify the Director-General and his staff for ever! We shall look with interest for the appearance of volume iv. with the Lower, and of volume v. with the Middle and Upper Oolitic divisions of the Jurassic rocks.

IV.—The Story of Our Planet. By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., etc. 8vo. pp. xvi. and 592, with 6 Coloured Plates and Map, and about 100 Illustrations. (London: Cassell and Co., Ld., 1894.) Price 31*s.* 6*d.*

IN writing "The Story of Our Planet," the author has aimed to produce a companion volume to that by Sir Robert Stawell Ball,

entitled "The Story of the Sun." Prof. Bonney thinks, and rightly, that there is already an ample supply of text-books, guides and handbooks, in the English language to satisfy the requirements of every living student, but, besides this class, there is a still larger body of intelligent educated persons who feel much interest in the history of the earth on which they live but who have neither the leisure, nor the inclination, to master the technicalities of any one branch of science, or to enter into their minute details: for this reason the author has striven, by avoiding too many references, and especially dry scientific terms, to make a really readable book for the public at large.

In the introductory chapter the author briefly alludes to the historical records of the rocks, and the fossils which they contain. After this introspection of the earth he proceeds to its extrospection, in relation to the other planetary bodies and the sun. He then deals with the land-regions, their distribution over the globe, and the manner in which they are raised up in the continents and depressed in the oceanic areas. From this he passes to the consideration of the aerial region, and he discusses the great air-envelope of our globe, and the movements to which it is subjected. The waters of our planet next claim attention; this section is illustrated by some useful coloured maps of the ocean-basins; that on p. 38 of the ocean-currents is, however, hardly satisfactory as a process-block, and a far better diagram ought to have occupied its place.

In part 2, the author describes the work performed by Nature's agents in sculpturing and moulding the solid framework of our globe. The first agent being the atmosphere, naturally includes the action of sun and wind in the disintegrating of rocks and soils, and the formation of sand-dunes and rock-pillars. It is difficult sometimes to define the limits of the action of sun and wind apart from that of rain and rivers, except, of course, in *so-called* "rainless districts."

The transporting power of rivers is next discussed and the means by which they remove the solid crust of the earth, both in suspension and solution. The action of ice as a sculptor of the rocks, and as a carrier of material from higher to lower grounds, and in the distribution of erratics over land and sea, is also described and illustrated.

The work of the ocean, although limited to the margin of the land, produces considerable changes, by additions and subtractions, along our coast-lines, and by alterations in the contours and the depths of channels near the mouths of rivers, and by the changes in shoals, sandbanks, etc.

Under the title of "the Proletariat of Nature," by which the author evidently means all the lower forms of animal and vegetable life, the Mosses, the Lichens, the Foraminifera, Radiolaria, Sponges and Corals, Professor Bonney discusses the effects which these humble but prolific organisms produce, either as conservators of the surface—as in the cases of Lichens, Mosses, and vegetation generally—or as actual builders-up of earth-masses, as in the case of Coral-reefs, etc.

Part 3 is devoted to the consideration of changes from within; commencing with movements of the crust of the earth, illustrated by the well known example of the Columns of the Temple of Serapis and the terraces on the Coast of Norway; and by faults and flexures of the strata; by volcanic action and its effects, on earthquakes, and the internal changes produced upon rock-masses within the crust itself.

Part 4 deals with the earth's story in past ages, and treats of meteors and the earth's beginning; of the eras and subdivisions in geological history, and the processes of reasoning by which they have come to be recognized; and so we pass from the Archæan era, to "the building of the British Isles," of Europe, and other continents; and, following the author, discuss the earth's life-history.

Part 5 embraces some theoretical questions, such as the "Age of the Earth;" "the permanence of ocean-basins and land-areas;" on "climatal changes," and "the distribution and descent of life."

This work is essentially, what its author intended it should be, a pleasant readable book. Most of its facts are the common property of many other such volumes on Physical Geography and Geology, such as Élisée Reclus' "La Terre," with a little more geology added, after the manner of "Lyell's Principles." The smallest possible space is given to the so-called Life-History of our globe, a subject which appears to us to be worthy to hold a place of far greater importance in the History of our Planet. If we except the figures of some of the fossils given, the illustrations are, as a rule, of a high class and will render the book attractive to the general reader, for whom it is intended.

We think this is a volume which will have many readers, both amongst young and old.

V.—Annals of British Geology, 1892. A Digest of the Books and Papers Published during the Year—with Occasional Notes. By J. F. Blake, M.A., F.G.S. 8vo. pp. 310, with 100 Illustrations. (London: Dulau & Co. 1893.)

PROFESSOR BLAKE is to be greatly congratulated on the third annual appearance of this most useful work. Whilst the volume is arranged almost precisely on the same lines as last year (*vide* Geological Magazine, 1893, p. 134), certain changes have been introduced. The critical notes are no longer dispersed amongst the text, but wisely gathered together in the form of an Introductory Review, "which," says the author in his preface, "can scarcely be objected to if we admit the principle that 'thou shalt not muzzle the ox that treadeth out the corn,'" especially, we might add, if he treadeth not *on* the corn—of another.

The illustrations are now, as far as possible, of full size and interspersed in the body of the text. All new British species, save those in the Palæontographical Society's volume, are figured, with some few others of special interest.

We are still of opinion that the "Foreign Geology (published in

Britain)" were better omitted altogether, and fail also to see the object in practically reprinting such a work as that by Hudleston and Wilson.

Beyond this we have no adverse criticism to offer, and most sincerely deplore the necessity Professor Blake will be under of abandoning this work in the future unless the present volume meets with sufficient support. Aid should certainly be given him not only by individual geologists, but by those societies, large and small, that in many quarters of the British Islands are formed to promote the study and progress of the science of geology.

Unfortunately the principal society does not consider Records are "instituted for the purpose of investigating," or aiding in the investigation of, "the mineral structure of the earth;" whilst it is hopeless to expect the Geological Survey of the United Kingdom to be as enterprising as its American equivalent in the United States, and to undertake a work of utility such as this.

Those prepared to support Professor Blake should remember, "bis dat, qui cito dat!"

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—December, 6th, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:

1. "The Purbeck Beds of the Vale of Wardour." By the Rev. W. R. Andrews, M.A., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

The authors have obtained better evidence than previously existed for calculating the thicknesses of the several parts of the Purbeck series in the Vale of Wardour, and comparing the different subdivisions as developed in that Vale with those exposed in other localities. Putting together 22–24 feet of basement-beds of the Lower Purbeck strata seen in the Wockley section, 21 feet in Ridge Quarry, and 17 feet in Teffont Quarry, more than 60 feet of Lower Purbeck Beds are actually seen, and allowing for the gap between the Wockley and Ridge sections, 70 feet seems a fair estimate of the average thickness of the Lower Purbeck strata.

In the Teffont and Chicksgrove quarries, a little over 12 feet may be measured between the basal clay of the Middle Purbeck Beds and the Cinder Bed; while the great cutting on the Teffont line shows 19 feet of strata above the Cinder Bed, and the beds of Dinton cutting may be all on a higher horizon; so that an estimated thickness of 32 feet for the Middle Purbeck Beds is probably below the mark.

The clay and sand in the Dinton cutting must be 18–20 feet thick, and between its summit and the top of the second seam of calcareous grit there is a thickness of at least 8 feet. This grit forms the floor of Dinton Well, about 40 feet deep; hence there is a thickness of at least 66 feet of Upper Purbeck strata, and probably more than 2 and less than 12 feet in addition.

A comparison is instituted between the Purbeck Beds of the Vale of Wardour and those of the Dorset coast, etc., and some remarks are made upon the physical conditions under which the beds were deposited.

2. "On a Picrite and other Associated Rocks at Barnton, near Edinburgh." By Horace W. Monckton, Esq., F.L.S., F.G.S.

The object of this paper is to describe a cutting on a new railway in Barnton Park, where there is an excellent exposure of picrite. It consists of serpentinized olivine, augite, mica, iron oxide, and a little plagioclase-felspar, with a variable amount of interstitial matter. In many respects it comes very near to the picrite of Inchcolm, which island is 4½ miles north of Barnton cutting. It differs from the picrite of Bathgate, and the probability is that the Barnton rock is an offshoot from the same magna as that which supplied the Inchcolm rock.

Besides the picrite other igneous rocks from the same cutting are described—in particular, a rock with porphyritic crystals of a green mineral replacing olivine, or more probably augite, and a great quantity of brown mica in small flakes and crystals. It is suggested that the name of mica-porphyrite might be given to this rock.

3. "On a variety of *Ammonites* (*Stephanoceras*) *subarmatus*, Young, from the Upper Lias of Whitby." By Horace W. Monckton, Esq., F.L.S., F.G.S.

The author describes an ammonite found by himself in 1874 near Sandsend, 3 miles north-west of Whitby. He thinks it was not actually *in situ*, but lying with a number of nodules on the floor of an old alum-pit, although he has no doubt that it is from the Alum Shale of the Upper Lias. A peculiar arrangement of the costæ as they cross the siphonal area distinguishes the specimen from other Whitby ammonites known to the author. It bears a strong resemblance to a shell figured as *A. subarmatus* by D'Orbigny, "Terr. Jurass.," pl. lxxvii., but is unlike the figures of that species given by other authors.

II.—December 20th, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Stratigraphical, Lithological, and Palæontological Features of the Gosau Beds of the Gosau District, in the Austrian Salzkammergut." By Herbert Kynaston, Esq., B.A. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.)

This paper, after referring to the previous literature of the subject, treats of the situation and physical aspects of the Gosau Valley, the distribution of the Gosau Beds, their stratigraphy, palæontology, and geological horizon, and the physical conditions under which they were deposited, and comparison is instituted between the Gosau Beds and the equivalent beds of other areas. The author shows that Hippurites occur at two horizons in the Gosau Beds,—a hippurite-limestone immediately above the basement-conglomerate being characterized essentially by *Hippurites cornu-vaccinum*, which is

overlain by *Actæonella*- and *Nerinæa*-limestones and an estuarine series, and above these is a second hippurite-limestone characterized essentially by *Hippurites organisans*. It is pointed out that Toucas similarly distinguishes two Hippurite zones in Southern France; the lower, characterized essentially by *H. cornu-vaccinum*, being placed by him at the top of the Turonian System, whilst the second, with *H. organisans*, is referred to the summit of the Senonian; and the author gives reasons for regarding the Gosau zones as the equivalents of those of the South of France, in which case the Gosau Beds will represent the uppermost Turonian and the whole of the Senonian, *i.e.* the zones of *Holaster planus*, *Micraster*, *Marsupites*, and *Belemnitella mucronata* in England, whilst the upper unfossiliferous beds may be the equivalents of the Danian Beds.

The strata are, on the whole, of shallow-water origin, and were deposited in shallow bays in the Upper Cretaceous sea of Southern and Central Europe, on the northern flanks of the Eastern Alps. Probably towards the close of Upper Cretaceous times the southern area of the Gosau District was cut off from the sea to form a lake-basin in which the upper unfossiliferous series was deposited.

2. "Artesian Borings at New Lodge, near Windsor Forest, Berks." By Prof. Edward Hull, M.A., LL.D., F.R.S., F.G.S.

The boring described in this paper was carried down from a level of about 220 feet above Ordnance-datum, through the following beds:—

	Feet.
London Clay ... ... } Lower London Tertiaries	214
Chalk	725
Upper Greensand	31
Gault	264
Lower Greensand	7

The Chalk was hard, and contained very little water; but on reaching the Lower Greensand the water rose in the borehole to a height of 7 feet from the surface.

The author discusses the probability of the Lower Greensand yielding a plentiful water-supply in the Windsor district.

3. "Boring on the Booysen Estate, Witwatersrand." By D. Telford Edwards, Esq. (Communicated by the President.)

An account is given of a boring on the Booysen estate, situated about 2 miles from Johannesburg, and about 5000 feet south of the nearest point of outcrop of the "Main Reef" of the Witwatersrand. The "Bird-Reefs" crop out generally at a distance of 4000 feet south of the main Reef.

The borehole, 1020 feet deep, passed through sandstones (often micaceous), quartzites, and conglomerates, the last-named having a collective thickness of 91 feet 7 inches, the two thickest reefs being respectively 26 and 22 feet thick. The dip of the beds was 35°. Traces of gold were obtained. All the reefs were highly mineralized, principally with iron-pyrites, and belonged to the "Bird-Reef" series which overlies the Main Reef.

III.—January 10th, 1894.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Rhætic and some Liassic Ostracoda of Britain." By Prof. T. Rupert Jones, F.R.S., F.G.S.

In this paper the published observations on the occurrence of these Microzoa in the Rhætic and Lower Liassic strata of England, chiefly in Gloucestershire and Somerset, by the Rev. P. B. Brodie, H. E. Strickland, C. Moore, and others, are first of all recorded; and the various notices of the so-called *Cypris liassica* in various palæontological works are considered. Numerous specimens submitted by the Rev. P. B. Brodie, the Rev. H. H. Winwood, and Mr. E. Wilson, and some few examined in the Geological Society's collection, have been studied, with the result of determining, it is hoped satisfactorily, the characters and alliances of *Darwinula liassica* (Brodie) and of six or seven other species found in the same and the associated series of strata. The *Darwinula globosa* (Duff), from Linksfield, Morayshire, is also critically re-examined as one of this interesting series of Rhætic Ostracoda. The other species belong for the most part to *Cytheridea*; thus most of them probably lived in brackish or estuarine waters.

2. "Leigh Creek Jurassic Coal-Measures of South Australia: their Origin, Composition, Physical and Chemical Characters; and Recent Subaerial Metamorphism of Local Superficial Drift." By James Parkinson, Esq., F.G.S., F.C.S.

This paper contains an account of the lignitic coal of Leigh Creek and associated rocks. Analyses are given, as illustrating comparisons between the Leigh Creek coal and Jurassic and other coal-bearing rocks found elsewhere. The author discusses the origin of the Leigh Creek deposits, and describes certain peculiarities noticeable in the superficial materials, which he discusses in another paper.

3. "Physical and Chemical Geology of the Interior of Australia: Recent Subaerial Metamorphism of Eolian Sand at ordinary atmospheric temperature into Quartz, Quartzite, and other stones." By James Parkinson, Esq., F.G.S., F.C.S.

South of the Flinders Range fragments of stone of all sizes are found on the ground, the origin of which the author discusses. He maintains that they were formed by subaerial metamorphism of Eolian deposits.

CORRESPONDENCE.

ACTION OF GLACIERS.

Sir,—I wish to call the attention of geologists more experienced than myself to the Eidfjordsvand, in Norway, from which I think important lessons may be learnt.

The Eidfjordsvand is a lake about 4 miles long and 245 feet deep, and is remarkable for its desolate grandeur. The river that forms the Vöringfos flows through it into a branch of the Hardangerfjord,

which is called the Eidfjord, and is about three-quarters of a mile below the lake.

Between the lake and the fjord is the old delta of the river, rising, I should say, 150 feet above its present level.

The problem is, how can the delta be where it is, without the lake being filled? My explanation is that the lake has been filled by the delta, and has been cleared out by a glacier. If this explanation

be correct it has important bearings on the action of glaciers. I do not think, from its position at the head of a branch fjord, remote from the sea, where the tides must necessarily be weak, that what I have called a delta can be entirely, or even mainly, a sea-beach; this point, however, might be investigated by someone who could devote more time to the question. WILLIAM CHURCHILL.

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THE SUBMARINE CRUST.

SIR,—It is obviously a matter of interest to obtain some knowledge, however slight, about the constitution of the earth's crust beneath the great oceans. The fact that they are covered by a deep layer of water, while it precludes the possibility of examining the subjacent rocks directly, gives an opportunity for gaining some information about them from considerations based upon their attractive force upon the water itself. I have accomplished something in this direction in chap. xvii. of my "Physics of the Earth's Crust," supplemented by chap. xxvi. added in an Appendix.

In his "Introductory Review" to "Annals of British Geology, 1893," Professor Blake has thrown a doubt upon my work. In fact he has given it as his opinion that my calculations are unsound. Your MAGAZINE is not a suitable medium for a mathematical discussion, but I hope you will allow me just to say, that I do not admit the validity of any of the three objections he has formulated; but affirm them to be altogether erroneous. O. FISHER.

HARLTON, CAMBRIDGE.

OBITUARY.

THE REV. GEORGE GORDON, LL.D.

News has reached us of the death of this veteran geologist, at the advanced age of 92. Born in the Manse of Urquhart, Morayshire, on 23rd July, 1801, the son of the late Rev. William Gordon, minister of Glenlivet, he entered Marischal College, Aberdeen, in 1815, graduated in 1819, and afterwards studied divinity at Aberdeen and Edinburgh. He was licensed to preach by the Presbytery of Elgin in 1825, and was presented to the parish of Birnie in 1832 by the patron, Francis, Earl of Moray.

He was thus for 67 years a minister of the Church of Scotland, 57 years of which he ministered uninterruptedly to the parish of Birnie, near Elgin. He was the second oldest minister in the Church, and one of the two oldest graduates of the University of Aberdeen.

From his youth upwards Dr. Gordon was devotedly attached to the study of Natural History. In 1839 he published "Collectanea for a Flora of Moray," which is regarded as a standard authority on the botany of the county, and he was instrumental in adding the plant *Pinguicula Alpina* to the British flora. He also contributed papers on the fauna of Moray, with which he was equally conversant, to the "Zoologist." As regards archæology, and in fact in all matters of local antiquarian interest, he was an industrious collector, and might always be found to the front investigating anything new about anything old. In the branch of geology, there has been nobody in the neighbourhood of Elgin who has pursued a closer study nor acquired such an intimate knowledge of the subject. The formation of the Old Red Sandstone, in particular, long engaged his attention, and nothing could excite in him a livelier interest than any new discovery of fossil remains. In fact in every such case it was customary for the finder to appeal to Dr. Gordon of Birnie for an explanation.

He was ever ready to impart his knowledge to others, and felt pleased when anyone sought to share in his investigations: his enthusiasm even at the great age of 90 being most encouraging to witness. Among his geological services may be mentioned the procuring of remains of a number of fossil reptiles from the Elgin Sandstone, some of which have been described by Prof. Huxley, others quite recently by Mr. E. T. Newton; the more recent discoveries include a number of very remarkable forms, and one of these, a new *Dicynodont* genus, has been named *Gordonia*. Dr. Gordon maintained steadfastly the view that the Elgin Sandstones belonged to one continuous series of Old Red Sandstone age; a view that is not supported, however, by palæontological evidence.

His efforts in connection with the Elgin Museum are well known. Along with other gentlemen of kindred tastes, he was influential in founding the Elgin and Morayshire Literary and Scientific Association.

Although in November last nobody would have expected on seeing